1 NON-TECHNICAL SUMMARY

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1.1 Introduction

What you are holding in your hands is the *Strategic Environmental Assessment Report for the Polish Nuclear Programme.* This study was meant as an objective and impartial analysis of all known and foreseeable environmental impacts that may arise from the development of nuclear power in Poland.

Without exaggeration, we can say that Poland is facing a great challenge – modification and development of its energy sector. Commencement of the national nuclear energy programme should be part of this development – in terms of both technology and organisation. At present, nearly all industrialised countries in the world make use of nuclear energy. Countries such as Italy, Sweden, and the United Kingdom have included the development of nuclear power in their plans. In addition, 50 developing countries have applied to the International Atomic Energy Agency for IAEA's assistance in the development of their nuclear energy programmes. As we can see, Poland is no exception to the general trend – focus on the development of the country's nuclear sector.

We must note that there are important reasons to support modernisation of the energy sector in Poland, including the development of nuclear power. So far, the country's power sector has been based almost entirely on coal, which is clearly contrary to the international focus on environmental protection. In the coming years, Poland will be forced to pay high charges for carbon dioxide emissions, and after 20 years we will see an unavoidable increase in electricity costs and the Polish industry will ultimately become uncompetitive.

In line with the principle of diversification of energy sources, it is necessary to explore renewable energy sources (RES) despite the considerable costs associated with their use. With the technologies currently available, RES will not satisfy the ever-increasing demand for electricity. One of the reasons is that renewable energy sources, such as wind and solar energy, are intermittent. Therefore, we need a reliable and cheap source of energy produced in baseload power plants – producing energy at a constant rate that meets the continuous energy demand of all users. Nuclear power plants may serve as a cheap and clean energy source – provided that they have no negative impact on ecosystems or people's health and well-being.

This Report is the first-ever attempt at a comprehensive study of the impact of nuclear energy on the natural environment in Poland, including all its components, as well as on the living environment and health of humans. The Report was developed by a team of authors with in-depth knowledge of environmental protection, enhanced with the input of recognised experts in the field of nuclear energy who have studied its environmental impacts for a number of years, and presents all aspects of the expected impact of the Polish nuclear programme on the country's natural environment. The current state of the environment in Poland, as well as all requirements relating to the protection of various species of plants and animals, are described in detail. The findings are presented on maps, depicting both the protected areas and the suggested siting of nuclear power plants. The existing environmental constraints are described and estimated for all short-listed locations of nuclear power plants.

The Report also discusses the possible consequences of the 'zero-option', i.e. withdrawal from the programme and from the plan to build nuclear power plants (no action alternative). The complete end-to-end process of electricity production in nuclear power plants is discussed in detail. The Report focuses on radiological safety and accident prevention methods that are applied to effectively eliminate the possibility of any breakdown similar to the Chernobyl disaster. In accordance with the international requirements, the Environmental Impact Assessment includes not only the operational phase of a nuclear power plant, but also its construction and decommissioning. The Report also contains a detailed description of the impact of individual phases of the project (construction, operation, and nuclear decommissioning phase) on biodiversity, human health, plants and animals, water, air, the Earth's surface, landscape, climate, natural resources, historical buildings, and material goods.

Although the Report cannot be used as a decisive factor that will determine the location of the first nuclear power plant in Poland, it will serve as a source of valuable information on the possible local impacts of any project that can be used by the investor, the society, and administrative bodies and authorities. At the same time, it will put the environmental aspects in the spotlight, next to the social, political, or economic considerations. It is of key importance for the country's sustainable development.

This summary is an integral part of the Report and should not be treated as a separate document. The summary recaptures the key information presented in the main body of the Report in a synthetic and condensed manner, avoiding the technical and specialist language (whenever possible). In many cases (for example, the location analysis), more inquisitive readers may feel more inclined to read the main report. By all means they are encouraged to do so.

1.2 About the Report

The Strategic Environmental Assessment Report for the Polish Nuclear Programme (hereinafter referred to as the "Report" or "SEA Report") was prepared in accordance with the agreement signed by and between the Minister of Economy and the company Fundeko Łukasz Szkudlarek. The Report was based on draft Polish Nuclear Programme dated 16 August 2010 and the position of the General Director of GDOS (General Directorate for Environmental Protection) and Chief Sanitary Inspectorate regarding the scope of the Strategic Environmental Assessment Report for this document.

The Polish Nuclear Programme – background

The decision to develop the Polish Nuclear Programme was adopted by resolution of the Polish Council of Ministers No. 4/2009 of 13 January 2009 on actions taken to develop the Polish nuclear power sector. On 10 November 2009, the Council of Ministers adopted the Polish Energy Policy until 2030. One of the key priorities of the Policy is Diversification of the electricity generation structure based on the introduction of nuclear energy.

Adoption of the Policy was based on the Strategic Environmental Assessment of its environmental impacts, including also social consultations. Therefore, we must note that the present Strategic Environmental Assessment Report for the Polish Nuclear Programme is not a document that was meant to justify the introduction of nuclear energy in Poland (the rationale for the Polish Nuclear Programme has already been presented in the Strategic Environmental Assessment for Polish Energy Policy until 2030).

Contents of this SEA Report

The scope of the Polish Nuclear Programme covers mainly legal, organisational, and formal measures, and as such has no negative impacts on the natural environment. However, the outcomes of these activities will include the launch of the first two nuclear power plants in Poland. This Report focuses on the environmental impacts of these outcomes. The scope of this Report is in accordance with Art. 51 of the Act of 3 October 2008 on Access to Information on the Environment and its

Protection, Public Participation in Environmental Protection and on Environmental Impact Assessments (Journal of Laws No. 199 item 1227).

Methods applied in the Strategic Environmental Assessment

There are two basic methods applied to conduct a strategic environmental assessment:

- **Method 1** is applied to assess the environmental impacts of specific projects. The procedure consists in a number of separate assessments for every project with a precisely defined implementation framework. As a result, environmental impacts of a project are defined as precisely as possible and proven in a scientific manner. The review of alternatives is based mainly on location or technology alternatives within the adopted or evaluated option.

- **Method 2** is used to evaluate policies and strategic documents. The main goal is to define the objectives of the document itself and to evaluate their implementation – not the direct environmental impact of individual projects. This procedure is much less formal and more condensed than the first model. It focuses more on the relationship between the assessment and the decision-making process that includes the assessment as its integral part.

The Report basically applies the first method to analyse the possible environmental impacts resulting from the construction of the first nuclear power plants in Poland as foresightedly as possible, based on the available information regarding both the environmental impact of nuclear plants and their potential locations. Analyses included the scope of environmental impacts that may result from the planned installation of different types of nuclear reactors in Poland. The Report also focuses on the analyses of potential locations of nuclear power plants recommended by the Ministry of Economy, as well as their possible environmental impacts. For each of those locations, their potential environmental impacts were evaluated to the extent possible with the information available as at the date of the Report.

The assumptions and analytical methods adopted in the Report include:

- reference objects method - applying the impacts of a specific implemented project to the location of the planned investment. Monitoring data and the relevant EIA reports are used for this purpose.

- analysis and evaluation of emissions from nuclear power plants – analysis of radiological exposure that is the main source of concerns,

- analysis of impact on Natura 2000 areas based on available literature data,

- location analysis – GIS techniques are used in the analysis of project locations and cartographic visualisation,

- analysis of the Programme’s relations with other documents,

- analysis of potential social conflicts,

- economic aspects – the SEA Report does not include any economic analyses prepared by its authors – it was not the basic purpose of the Report. However, economic analyses presented in the existing publications were quoted and used in the Report to discuss certain aspects relating to environmental changes both for the no-action alternative and for all other alternatives.

We must strongly point out that the adopted methodology that focuses mainly on negative environmental impacts may be misleading both for the reader and for authorities that will evaluate the Report. Therefore, the Report also evaluates and presents certain positive environmental impacts of the Programme.

During the development of this Report, we encountered a number of problems that required an individual approach to problem solving. Some of these problems are presented in the following table.

PROBLEM	SOLUTION
• A large number of issues to study.	• A team of 14 recognised experts in various fields of study (connected with scientific circles) was appointed. • Analyses conducted as part of other studies and expert reports were used. • The reference objects method was used.
• Lack of hydrological data necessary to evaluate the sufficiency of cooling water resources for some locations (Bełchatów, Pątnów, Krzywiec, Lisowo, and Wiechowo). • Lack of detailed alternative location analyses (for all locations).	• The available hydrographical data as well as brochures and reports furnished by the suppliers of nuclear energy technologies were used. • Authors used the knowledge of experts and publications on the cooling systems as well as water and effluent management systems in nuclear power plants.
• No access to data on the implemented nuclear power projects including Generation III EPR, AP1000 and ESBWR reactors that will be potentially used in Poland.	• Information and knowledge offered by the IAEA expert was used – based on the analysis of reactors similar to those proposed for Poland. • To prepare the model of environmental impacts of Generation III nuclear power plants, we used monitoring data recorded for Generation II nuclear power plants that was extrapolated to Generation III projects, as well as data from safety analyses.
• Lack of detailed meteorological studies for individual typical locations (inland, coastal, in the vicinity of lakes and hills, etc.).	• Uniform weather conditions (plus a safety margin) were provisionally assumed for a typical location in Central Europe.
• No binding acts of law. The Atomic Energy Act and Resolutions of the Council of Ministers on nuclear energy have not been finally approved.	• The proposed regulations were assumed as the applicable guidance and were used to evaluate the impact of the future Polish nuclear power plant on the ecosystem and human health and well-being.
• Lack of precise data on the fauna and flora in specific locations.	• The evaluation of natural resources is as complete as possible, based on a very detailed analysis of the available scientific data.
• Authors were not able to verify economic calculations quoted in the Report.	• All sources of information presented in the Report were thoroughly analysed for their reliability, based on the quality of publications (references to source data and detailed description of methodologies applied) and the composition of the team of authors (consisting of experts in the field).
• The Polish Nuclear Programme does not present any concrete and consistent information on the target planned volume of electricity to be produced in nuclear power plants.	• Consistency of the adopted data with other documents (such as the Polish Energy Policy) was verified on a case-by-case basis. Sources of data were specified for all references to the specific amounts/quantities; the most realistic and probable data was selected.

1.3 References to other strategic documents

About 50 documents relating to energy in general and nuclear energy in particular were analysed in terms of the protection of the natural and human environment. We have reviewed documents prepared at the Community, national, and regional level, as well as documents constituting the international body of law for the nuclear power sector. This review indicates that the structure of the energy sector in Poland must be modified, mainly to ensure compliance with the global trend of reducing air pollution and CO2 emissions. The majority of strategic documents in Poland provide that the share of conventional energy sources should be reduced in favour of the RES technologies (wind, geothermal power, water, biomass burning). This reduction seems by all means justified, especially considering the very alarming information regarding the condition of the natural environment near brown coal mines. However, alternative ‘clean’ methods are subject to certain limitations and often have a very strong impact on certain components of the environment, including the reduction in the number of some species of animals (this problem applies mainly to wind power plants and hydroelectric power plants). The high cost and the relatively low profitability of many RES projects are also highlighted.

With only few exceptions, the analysed national strategic documents say nothing about the development of the nuclear power sector in Poland. It does not come as a surprise, because they had been prepared before works on the Polish Nuclear Programme were closed. It means that at that time, nuclear energy was not given a green light in Poland. Also, the criteria for the selection of individual locations for nuclear power plants and the type of reactors to be used were not clear. Therefore, the scale and the type of impact of these projects on individual components of the natural environment could not be determined.

The first mention of the possible introduction of nuclear power technologies can be found in *Polish Energy Policy until 2030 with Annexes and the Strategic Environmental Assessment Report for the Polish Energy Policy until 2030 (final report).* They indicate the potential positive role of nuclear energy in the reduction of harmful emissions to the atmosphere in accordance with Poland’s obligations assumed at the time of the country’s accession to the European Union. At the same time, the said Report highlights the controversies surrounding the construction of nuclear power plants and management of nuclear waste, consisting mainly in the failure to organise the national debate and gain the social approval for the Programme.

Our review of international documents, starting from American documents generally considered to be examples of best practice, through the requirements and guidance of the IAEA, up to the nuclear power conventions signed by Poland, indicates that their authors consider nuclear power to be a model sector of the industry – ensuring clean air, water and soil, and generating cheap and reliable electric energy. Nuclear power plants proposed for Poland must meet the most stringent requirements for radiological protection and safety. At the moment of introduction of nuclear energy to the Polish economy, there is an extensive body of international law that can be used to our benefit.

1.4 Current state of the natural environment in Poland

When determining the current condition of the natural environment in Poland, all its basic components were evaluated separately, specifically taking into account the aspects relating to the potential development of the nuclear energy sector in Poland.

Natural topography (relief) and land use structure

Natural topography or land relief is one of the main elements of the environment that determines both its internal structure and the rate of energy and matter cycle. In Poland, land relief is diversified and poses a complex problem from the perspective of variability of terrain forms and their origin.

Generally speaking, today's land relief structure in Poland can be divided into a series of alternating belts of lowlands and uplands arranged into east-west-trending zones, which resulted from long-term natural internal and external processes.

Surface of the land is changing – also as a result of human activity. In recent years, i.e. from 2000 to 200', the share of woodland areas in Poland's total surface area has increased at the expense of arable land, meadows and pastures (grassland). This trend is confirmed by the studies of the Central Statistical Office. The share of orchards has also increased slightly. At the same time, the share of built-up and urbanised areas has increased considerably, particularly in the vicinity of large cities where the suburban areas, including large housing estates, have developed.

Seismic activity in the Earth's crust – earthquakes

Poland is generally considered a safe region in terms of the country's seismicity. The last large earthquakes occurred in this area about 150-200 million years ago. However, both historical data and present-day records indicate that seismic activity in Poland is a permanent phenomenon. It may be caused by natural factors and by human activity in mining areas.

The majority of earthquakes recorded in the past originated in the Czech Republic, Hungary, or somewhere else in Europe. They were quite common in the Karkonosze Mountains, the Kłodzko Valley, the Carpathian Mountains, and the Carpathian Foothills (Subcarpathian Region). Only a small number of these earthquakes caused building disasters, usually damaging the structure of churches and houses. Silesia was the region that recorded the highest seismic activity. However, almost all earthquakes in this region were caused by mining activities. Earthquakes recorded in Bełchatów (for instance in 1980 or in 2001) and in the LGOM (Legnicko-Głogowski Copper Mining Area) had a similar origin. In 1992–1993, a series of earthquakes was recorded in the Beskids (Beskid Sądecki and Beskid Niski Mountains). Similar series of quakes were recorded in September 1995 in the Podhale Region. In more recent years, earthquakes that originated in the area of Baltiysk in Sambian Peninsula (Kaliningrad Oblast) on 21 September 2004 made the headlines. They were probably the strongest earthquakes in this region in the past 1000 years.

However, we must emphasise that the magnitude of these earthquakes does not compare to high-seismicity areas, and they are caused mainly by the mining activity. In the European scale, let alone the global scale, the seismic activity is Poland is low. Detailed analyses of data recorded by special seismometer stations indicate that no strong, large, or major earthquakes have been recorded in Poland since 1964. Therefore, earthquakes recorded in the analysed period carried no risk of major infrastructural damage. Still, 21 earthquakes of medium magnitude have been recorded. These earthquakes could potentially cause damage of medium severity. The strongest earthquake in this period was recorded on 1 April 2000 near the town of Żerków, SE of Poznań. Other larger quakes occurred mainly in the southern part of the country, and also up north – in the Kaliningrad Oblast and the Bay of Gdańsk. Medium–magnitude quakes originate mainly in the SW part of Poland – the regions of Lower Silesia, Lubuskie, and Wielkopolska (Greater Poland). Single earthquakes of this magnitude were also recorded in the regions of Upper Silesia and Małopolska (Lesser Poland).

The problem of earthquakes is important from the perspective of structural safety of power generating facilities, and as such was discussed by the International Atomic Energy Agency (IAEA). A standard nuclear power plant must be designed to withstand the so-called *Design Basis Earthquake* (DBE). Designers of nuclear power plants must prove that the plant will meet all safety parameters (for given ground conditions). For all structures, systems, and elements that are considered essential for nuclear safety, a location-specific Seismic Margin Assessment (SMA) will be introduced.

Surface and ground waters, and the risk of floods in Poland

The amount of water per capita in Poland is among the lowest in Europe – only about 1700 cubic meters per annum (the average for Europe is about 4500 cubic meters per year per capita). Therefore, higher-quality ground waters are used for drinking, while surface waters are used for other purposes (mainly economic activity). The total area of surface waters in the territory of Poland is 640.5 thousand hectares (in 2008), which represents a major decrease compared to 2000 (about 830 thousand hectares). These values indicate that the resources of surface water in Poland have been shrinking. However, water supply quality problems are still more serious than quantity-related problems. The quality of waters in Polish rivers has been improving steadily, but still the majority of watercourses are considered “unclassified”, i.e. not meeting the standards mainly due to their sanitary condition.

Major Ground Water Reservoirs (MGWR) were selected in the territory of Poland. They include natural water bodies located in underground deposits that collect groundwater and meet the specific quality and quantity criteria. 163 MGWRs were selected, of which 53 were classified as top-quality reservoirs.

High water levels in rivers are a major problem in Poland. They represent the most common environmental risks in the country. Increasing water levels in river beds are natural phenomena than cannot be avoided. Floods in Poland have different origins, severity, and dynamics, but they always involve an outflow of water from river beds into floodplains. Floods are associated with areas occupied or used by humans, not river valleys in their natural state.

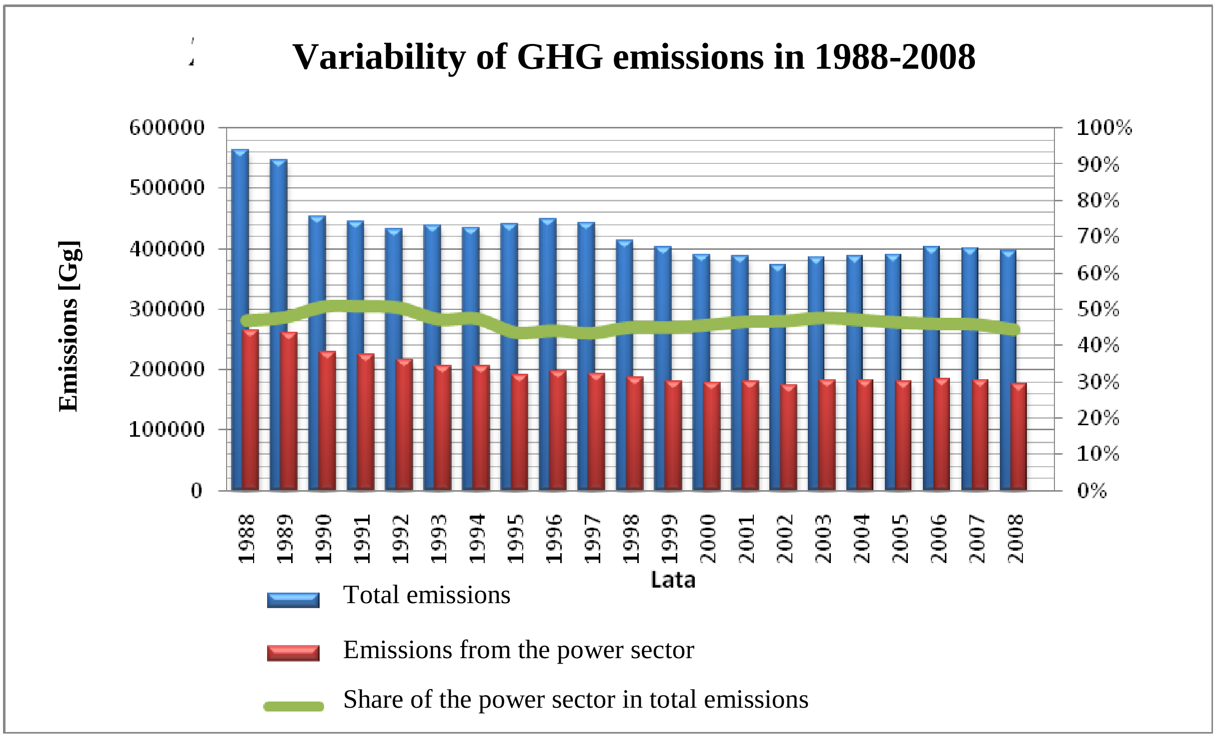
The most recent floods that occurred in 2010 have yet again exposed the gaps in the Polish system of flood protection. Rivers would break flood defences and flood the bottoms of river valleys. To make matters worse, the public was not properly informed about the flood threats and risks.

Condition of atmospheric air in Poland and emissions of air pollutants

Given that pollutants can move freely through air, air pollution poses the most serious environmental threat – it cannot be contained within a specific area. Air pollution is recorded if air is composed of any gases, liquids or solids that do not constitute the natural components of atmospheric air, or if their concentration exceeds the natural composition of the Earth’s atmosphere.

The 2008 annual air quality assessment commissioned by the Chief Inspectorate for Environmental Protection indicates that the overall condition of air in Poland is good. In most cases under analysis, the levels of gaseous pollutants were within the adopted standards. Dust is a more serious problem. The limits of dusts in atmospheric air are exceeded mainly due to emissions from individual building heating systems or due to unfavourable weather conditions during tests and traffic-related emissions.

The Polish power sector is also the key pollutant responsible for large emissions into the air. The largest portion of these emissions comes from coal-fired power plants (using both lignite and bituminous coal). According to the international agreements, Poland is under the obligation to reduce its emissions of greenhouse gases. Considering that over 40% of the GHG emissions come from power plants, their reduction depends to a large extent on the modification of the country’s energy sector.



Variability of GHG emissions in 1988-2008; changes in land use and the forestry sector are not considered

Noise

The impact of noise on the environment, including on human beings, depends on the time and type of exposure. In Poland, road traffic is the main source of noise. In the power sector, individual components of power plants may be the key sources of noise – including starting valves and boiler safety valves, compressors, and ventilation fans. Minor sources of noise include transformer stations, fan cooling towers, and steam discharged from starting valves and safety valves. Fans, pumps, and turbines are usually enclosed in sound-absorbing housings.

Waste

The volume of waste produced in Poland has been decreasing steadily (from 138 million Mg in 2000 to 130 million Mg in 2008) which results mainly from the reduction of industrial waste (from 125 million Mg to 115 million Mg, respectively). On the other hand, an upward trend has been recorded in the production of municipal waste. However, municipal waste (about 12 million Mg per annum) represents a minor problem compared to industrial waste – only about 10% of total volume of waste generated in Poland.

Industrial waste includes mainly waste materials produced during the extraction and processing of mineral resources, as well as waste from power plants (ashes and slags). About 75% of industrial waste produced in Poland is recycled, compared to only 7% of municipal waste. The remaining portion is deposited.

Hazardous waste accounts for approx. 1% of the total volume of waste produced in Poland (about 1.5 million Mg per annum). 36% of hazardous waste is recycled, and the remaining portion is neutralised (61%, of which 19% by deposition) and stored (3%).

In Poland there are currently about 35 hazardous waste landfills – either separate landfills or designated sections of general landfill areas for waste other than hazardous or inert substances. Hazardous waste produced in Poland includes a small portion of radioactive waste generated when using radioactive substances in medicine, the industry, or scientific research. The total volume of radioactive waste processed per year is 40-100 cubic meters. In addition, research reactors in Świerk produce spent nuclear fuel of various degrees of enrichment. Radioactive waste is processed by the Radioactive Waste Neutralisation Plant (Zakład Unieszkodliwiania Odpadów Promieniotwórczych) that ensures partial recovery of chemical elements, reduction of the volume of waste, and waste solidification. Processed radioactive waste is deposited in the National Radioactive Waste Depository in the municipality of Różan, 99 kilometers from Warsaw, in the area of a former military fort. The Depository in Różan is the only radioactive waste depository in Poland. It is used mainly to deposit short-lived, low- and medium-active radioactive waste. However, there is no depository for high-active and long-lived waste. Spent nuclear fuel from Polish research reactors is temporarily stored in water pools at the facility in Świerk. This waste will be transported back to the country where the nuclear fuel came from, in this case to Russia, in accordance with the Global Threat Reduction Programme financed by the US Government.

Cultural resources

Cultural resources include movable (collections, ceramics, etc.) and immovable cultural assets (such as buildings and their parts), archaeological resources, and UNESCO World Heritage Sites. In Poland, the register of historical monuments and sites includes: 64,673 immovable objects (as at 4 October 2010), 352,822 movable objects (as at 31 December 2007), 7,523 archaeological sites (as at 30 June 2009), and 13 UNESCO World Heritage Sites. The province of Podkarpackie has the largest number of historical monuments and sites, followed by Dolnośląskie, Mazowieckie, Małopolskie and Wielkopolskie provinces. Therefore, the southern and central parts of Poland are places to look for historical monuments. They are relatively less numerous in the northern part of the country.

Biotic elements of the natural environment and protected sites

Plants

Poland's vegetal cover includes plant species (flora) and plant communities (vegetation). Its natural diversification is lower than at the corresponding latitude in North America or Asia. It results mainly from its geological history (for instance, the impact of the continental glacier in the Pleistocene) and the many centuries of human activity. Compared to the rest of Europe, the diversity of natural plant cover in Poland is medium, which results primarily from the country's location in the moderate climate zone. Poland's plant diversity is higher than in the Nordic countries but lower than in the southern and western Europe.

Animals

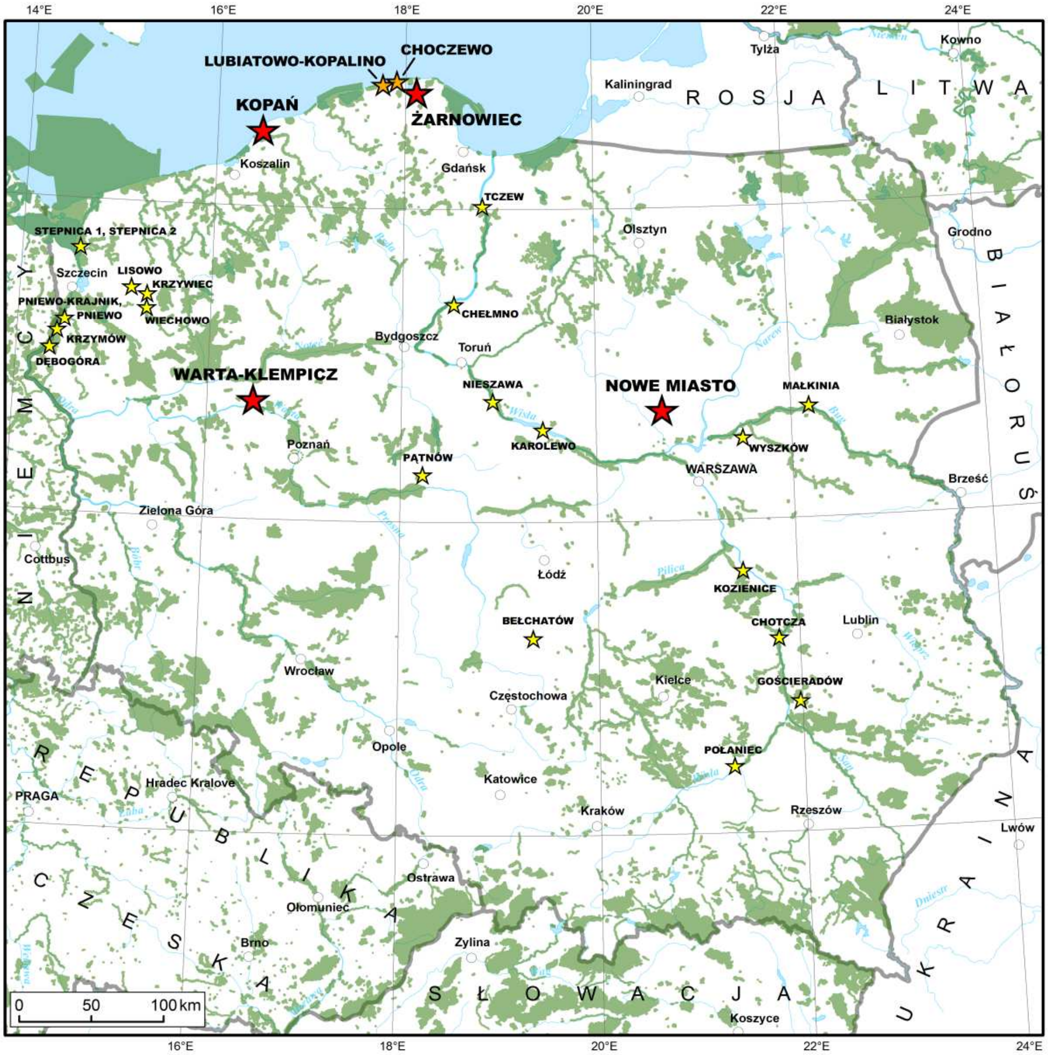
Polish fauna includes all present-day local species of wild animals (within their natural range) or foreign species that can be found in the territory of Poland. So far, about 36,000 species of animals have been recorded in Poland. The exact number is impossible to determine – on the one hand, new species are discovered all the time (both in Poland and in general), on the other – some species become extinct or change their natural range. Invertebrates account for the vast majority of Poland's fauna. However, vertebrates are the most researched group of animals, even though they represent only 2% of the country's fauna. They are found at the highest levels of the alimentary chains, and therefore are highly sensitive to any changes in their natural environment. Birds are a good indicator of the state of the environment – they are relatively easy to observe and react quickly to any changes in the environment.

Forms of nature protection in Poland

Within the meaning of the Act, protection of nature in Poland consists in the preservation, sustainable use, and renewal of the resources of the following components of nature: wild species of plants, animals and fungi (both protected and unprotected), natural habitats (both common and rare), elements of animate and inanimate nature, fossil plants and animals, as well as the landscape, green areas in cities and villages, and tree plantings/woodlots. In short, nature protection includes all its elements, as well as the landscape and greenery in human settlements. Effective protection of nature requires very specific provisions of law. In Poland, these provisions are found mainly, but not exclusively, in the Nature Protection Act of 16 April 2004 (Journal of Laws of 2004 No. 92 item 880).

Forms of nature protection in Poland include national parks, nature reserves, national scenic areas (the so-called landscape parks), protected landscape areas, ecological sites, inanimate nature documentation sites, nature and landscape complexes, monuments of nature, and ecological corridors. In accordance with the Community requirements, the European Ecological Network Natura 2000 was created. The purpose of Natura 2000 is to preserve endangered habitats as well as plant and animal species at a European level, as well as the typical and common habitats. Natura 2000 network includes two types of sites: Special Areas for Conservation (SACs) of Habitats and Special Protection Areas (SPAs) for Birds. Scientific criteria are the only factors taken into account when designating Natura 2000 sites.

POTENTIAL LOCATIONS OF NUCLEAR POWER PLANTS VS. NATURA 2000 SITES (SPECIAL AREAS FOR CONSERVATION OF HABITATS)



Proposed locations

★ recommended locations

★ backup locations

★ other proposed locations

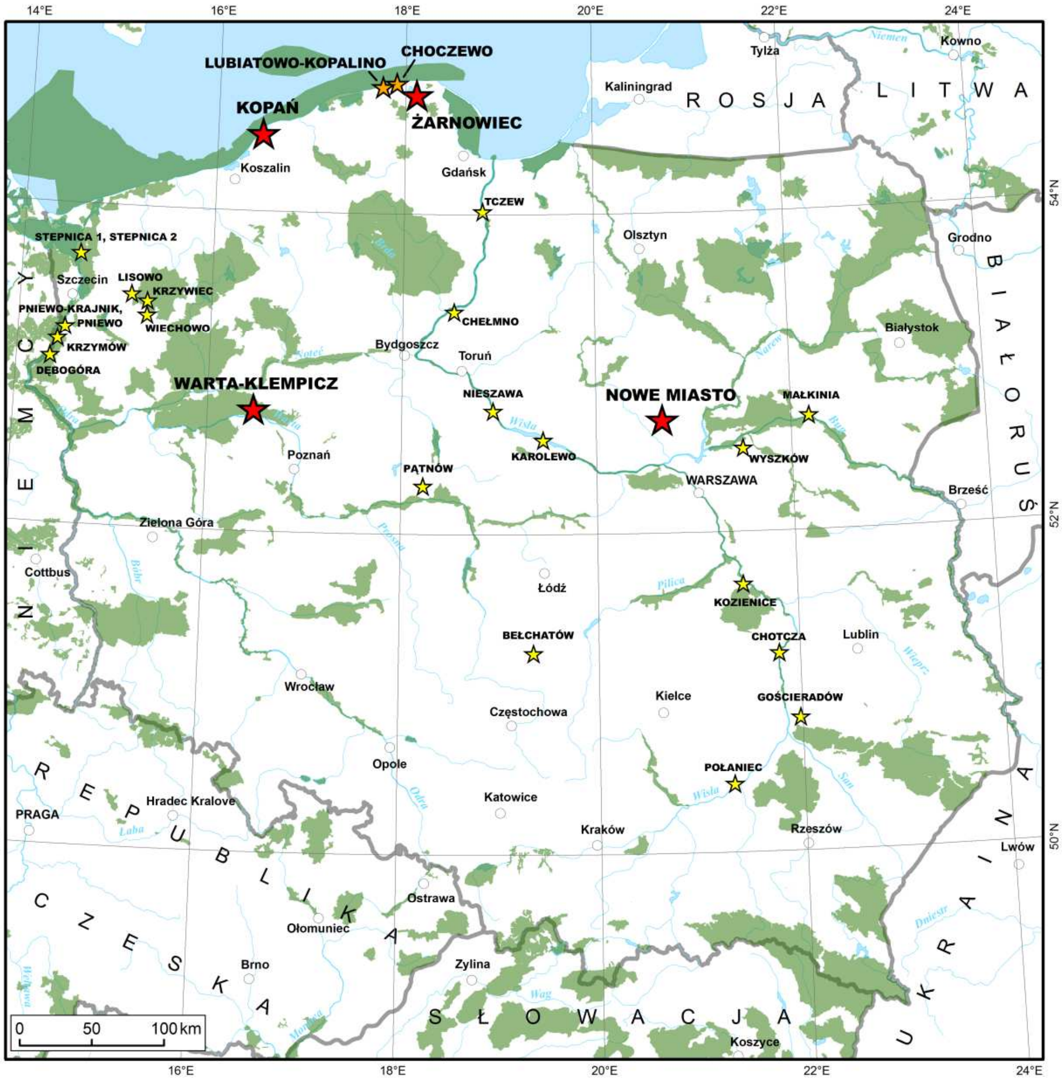
NATURA 2000 sites (SACs for Habitats)

Prepared by: mgr Kacper Jancewicz

Sources:
"*Ekspertyza na temat kryteriów lokalizacji elektrowni jądrowych oraz wstępna ocena uzgodnionych lokalizacji*" [Expert opinion concerning the siting criteria for nuclear power plants and preliminary evaluation of the agreed locations];
www.eea.europa.eu;
VMAP Level 0 (www.gis-lab.info)

Potential locations of nuclear power plants vs. location of Special Areas for Conservation of Habitats.

POTENTIAL LOCATIONS OF NUCLEAR POWER PLANTS VS. NATURA 2000 SITES (SPECIAL PROTECTION AREAS FOR BIRDS)



Proposed locations

- recommended locations
- back-up locations
- other proposed locations
- NATURA 2000 sites (SPAs for birds)

Prepared by: mgr Kacper Jancewicz

Sources:
"*Ekspertyza na temat kryteriów lokalizacji elektrowni jądrowych oraz wstępna ocena uzgodnionych lokalizacji*" [Expert opinion concerning the siting criteria for nuclear power plants and preliminary evaluation of the agreed locations];
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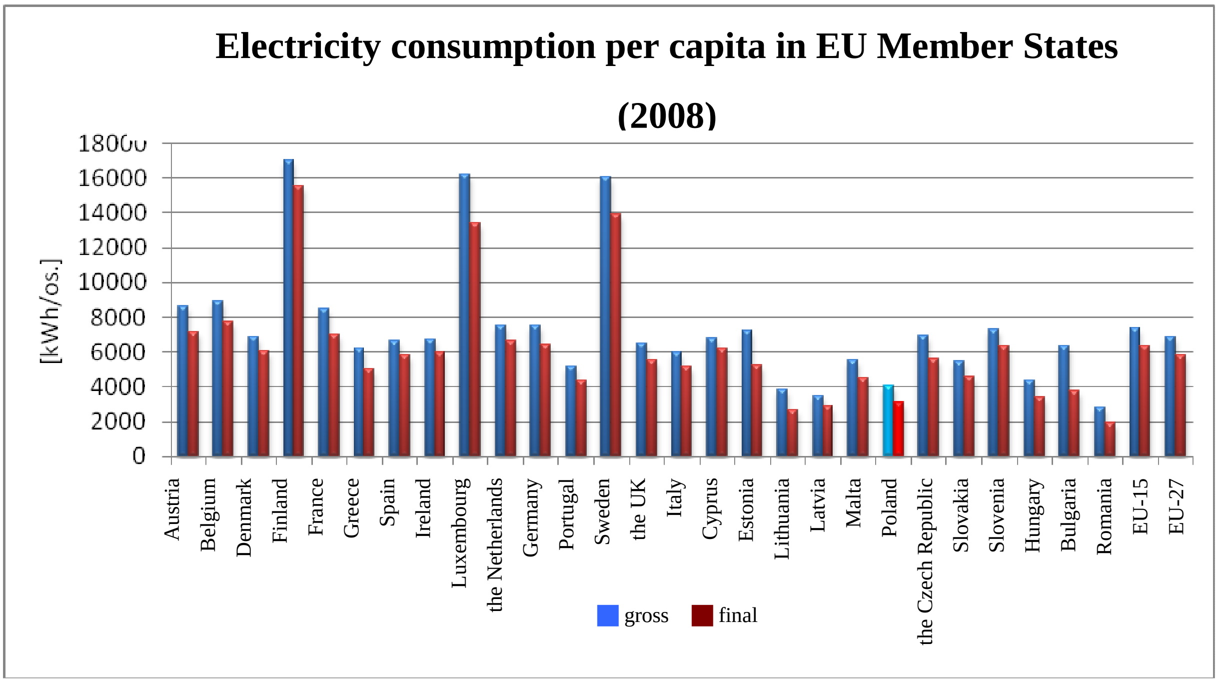
Potential locations of nuclear power plants vs. location of Special Protection Areas for Birds.

1.5 No-action alternative – impact on the natural environment in Poland

The current condition of the Polish power sector is highly unsatisfactory, especially given the predominant share of energy produced from coal and high emissions of pollutants. In the coming years, the sector will be forced to meet the ever-increasing requirements in order to achieve emission reduction levels adopted in the international agreements on the one hand, and to satisfy the ever-growing demand for electricity that ensures steady economic growth on the other. It is highly probable that these objectives are impossible to achieve at present. Therefore, new energy strategies need to be defined for Poland, with the Polish Nuclear Programme as one of their key elements. Adoption of the do-nothing option will mean that the consistent strategy of electricity generation in Poland will not be implemented. As a result, an energy crisis in Poland may become a fact, leading to an economic downturn and deterioration of the living standards for Polish citizens. Actions resulting in the postponement or withdrawal of the Programme could be justified if we expected a reduction in electricity consumption or the decision to continue (or even increase) the production of electricity from traditional sources (mainly black coal), whose resources are both limited and valuable for other purposes (potential application in the pharmaceutical sector, hi-tech sector, and chemical sector). The zero-option would also mean that emissions of air pollutants would remain at today's levels. As a result, Poland would be forced to pay high emission charges, and the Polish society would have to pay the high price of environmental pollution. Most of all, the no-action alternative would mean that Poland is left without any energy security strategy and that the country does not take any action to become independent based on diversified energy sources.

Electricity is a key element that ensures the proper functioning and development of any country. Today, the consumption of electricity in Poland per capita is 2.1 times lower on average than electricity consumption in the most developed Member States of the European Union.



Consumption of electricity per capita in EU Member States.
[prepared by: W. Kiełbasa based on Eurostat data (2010) and the Central Statistical Office data (2010)]

All forecasts of Poland's economic development provide that electricity consumption will continue to increase, despite the simultaneous improvement in the efficiency of electricity production and consumption.

To ensure a reliable comparison between the impact of the current electricity production system in Poland (based mainly on coal-fired power plants) and the new system planned in the Programme (assuming the steady growth of the nuclear power sector), we must consider not only the costs of electricity generation and purchase, but also costs of health effects caused by the resulting emissions, their impact on ecosystems, results of climate changes, etc. – that is, the total cost borne by the society. Analyses conducted in the Report according to the adopted calculation methods (ExternE and the cost curve) have demonstrated that the introduction of nuclear power in Poland is the most effective way to achieve the adopted goals (i.e. reduction of social costs and reduction of GHG emissions). At the same time, it is the most cost-effective method.

1.6 Nuclear energy – background information

Operation of reactors and nuclear power plants

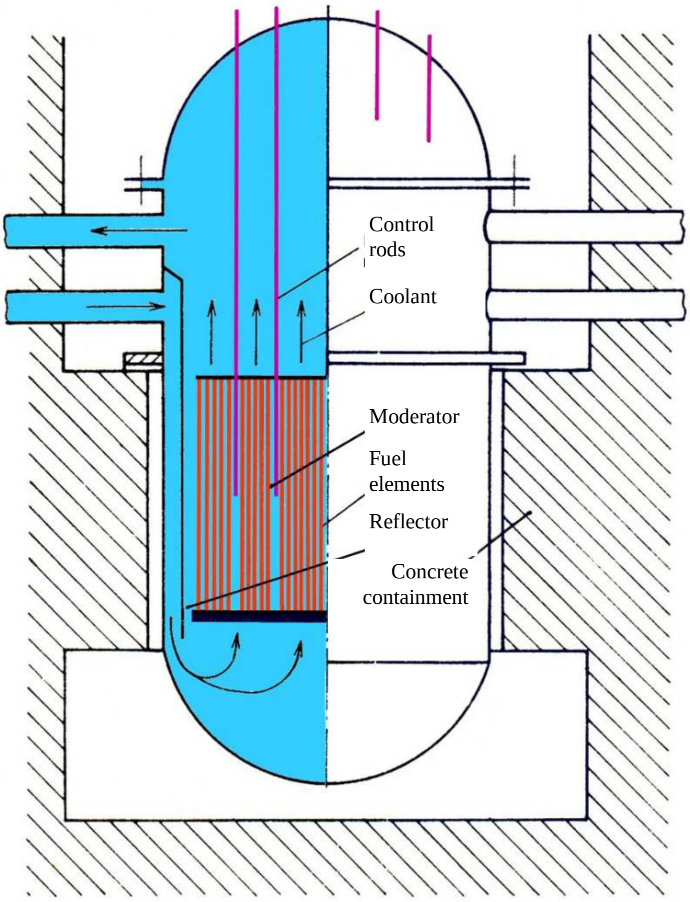
In a nuclear power plant, energy is generated as a result of a **controlled nuclear fission chain reaction** involving heavy nuclei of certain isotopes, especially the so-called 'fissile isotopes' of uranium (U-235, U-233) and plutonium (Pu-23', Pu-24'), occurring in a reactor as a result of the absorption of neutrons by the nucleus. This self-sustaining reaction is possible as the fission reaction produces 2 or 3 new neutrons that may induce new fissions. In a nuclear reactor, the chain reaction is controlled – that is, we are able to control the instantaneous balance of neutrons, and at the same time the amount of energy generated during this time (reactor power). Energy produced by nuclear fission of a single U-235 uranium nucleus is over 50 million times higher than energy produced by oxidation (burning) of coal to CO_2. As a result, a **very high concentration of energy** in achieved in nuclear power reactors, and nuclear power plants need much less fuel (in terms of its mass and volume) than traditional thermal power plants fired with fossil fuels. The vast majority of energy produced by nuclear fission is **collected in the form of heat** generated in the **nuclear fuel** material.

In a typical nuclear reactor, nuclear fuel takes the form of rods – the fuel material is enclosed in an airtight tube (the 'jacket') plugged at both ends. As a result, the **fuel element** resembles a rod:

The fuel element of a water reactor

About 200–300 such fuel elements are typically combined into **fuel assemblies or bundles**. In this form, nuclear fuel is used in nuclear reactors, where it is loaded and fixed on the so-called **reactor core**, i.e. the place where the controlled nuclear fission chain reaction takes place. Almost all power reactors use uranium enriched in U-235 (2-5%) or in plutonium (about 7%).

In the vast majority of nuclear power reactors (especially in light water reactors that will most likely be built in Poland), the core is enclosed in a pressure vessel (see the figure below). In addition to nuclear fuel, the reactor core contains the so-called ***moderator*** (a material that reduces the speed of neutrons to low energy values, where nuclear fission is more probable) and the ***coolant*** that flows in the bottom-up direction to the top section of the core, washing over and cooling down fuel rods by absorbing their heat generated by nuclear reactions.



Thermal reactor with moderator and water coolant

In a nuclear reactor, the fission chain reaction is controlled – i.e. only a pre-defined number of fissions per a unit of time are allowed. The fission reaction, and thus the reactor's power output, is controlled by using materials that have high absorption capacity for neutrons (boron, cadmium, indium, silver). Introduction or removal of absorbing materials to or from the reactor core regulates the number of neutrons in the core. All types of reactors have control rods that contain neutron-absorbing materials, and pressurised water reactors additionally contain coolant absorbents.

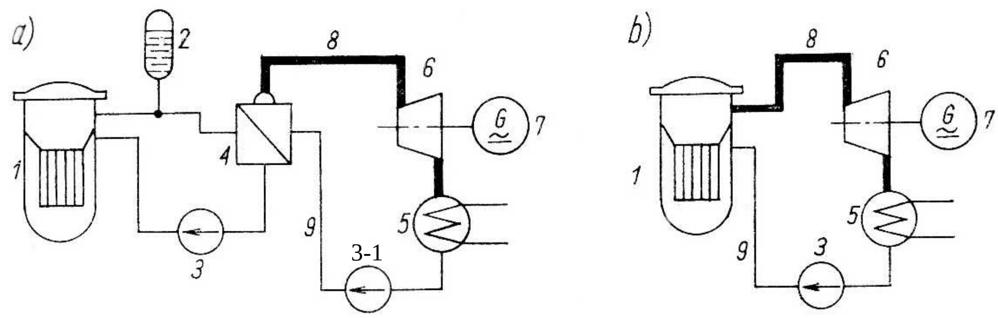
At the design stage, the proportion of the moderator vs. nuclear fuel is defined very precisely in order to achieve the most optimum performance parameters. When the moderator is heated as a result of an increase in power, its density is lower. It reduces the neutron slowing effect, which in turn leads to the decrease in the number of fissions. In addition, absorption of neutrons in fuel (by the non-fissile U-238 isotope) is increased. As a result, neutrons are lost – they cannot take part in the fission reaction. It creates a self-regulating effect, which is especially powerful in reactors with a water moderator.

It must be noted that the design of Generation III or III+ power reactors that are planned in Poland is completely different than the Chernobyl-type reactors (RBMK reactors) and a breakdown similar to the Chernobyl disaster (the so-called reactivity disaster – an uncontrolled sudden increase of power) is physically impossible in new-generation reactors.

There are many types of nuclear power reactors. The most common type of reactors used around the world is the Light Water Reactors (LWR) – they account for 82% of all nuclear power reactors in operation today. In LWRs, neutrons are slowed down (moderated) by ordinary water ('light' water, H_2O – as opposed to 'heavy' water, D_2O, where D stands for deuterium – a hydrogen isotope). Light water is also used as a coolant. There are two basic types of Light Water Reactors: Pressurized Water

Reactors (PWRs) and Boiling Water Reactors (BWRs). Nuclear power units offered currently to Poland include these two types of reactors.

PWR is the most common type of a nuclear power reactor (currently accounting for 61% of all reactors in operation around the world). The core is enclosed in a steel pressure vessel filled with *water* under high pressure (15÷17`MPa), which serves both as a *moderator* and a *coolant*. This pressure is high enough to prevent the boiling of water even at very high water temperatures (about 300°C) inside the reactor. Electromagnetic drives of control rods and safety rods are attached to the lid of the reactor vessel. Rods are moved up or down by the drives – inside or out of the reactor core. These movements of control rods regulate the nuclear fission reaction intensity and ultimately the reactor's output. The majority of neutron-absorbing rods are kept outside of the core. They are the so-called *safety rods*. If need be, all these rods may be dropped into the core, which will break the fission reaction immediately and shut the reactor down. Heat energy generated during the controlled nuclear fission chain reaction in the reactor core, and more specifically in nuclear fuel, increases the temperature of fuel elements. The reactor is connected to a cooling system, composed usually of 2 to 4 loops, where cooling water circulates in a closed–circuit system (primary loop). The primary loop is fitted with a pressuriser used to compensate water volume changes related to the changes in temperature and to maintain constant pressure in the system (see below).



Light Water Reactors: a) PWR, b) BWR

1 - reactor core, 2 –.pressuriser assembly, 3 – main circulation pump, 3-1 – supply pump, 4 – steam generator, 5 – turbine condenser, 6 – steam turbine, 7 – generator, 8 – steam, 9 – water.

Water from the primary loop flows to heat exchangers (steam generators) where its heat is absorbed by water circulating in the second closed-circuit loop (secondary loop), and after cooling down it is returned to the reactor. Pressure in the secondary loop (and in steam generators) is much lower than in the primary loop (6÷7 MPa). As a result, water in steam generators boils and evaporates. Water vapour so generated is supplied to a steam turbine, where it is depressurised going through subsequent levels in the turbine and transfers its energy to rotor blades, which starts the rotating movement of the rotor in a turbine. The rotor drives the synchronous generator where mechanical energy is converted to electric energy. After the turbine, water vapour is depressurised down to 0.0035 ÷ 0.0055 MPa and cools down, moving to the turbine condenser where it undergoes condensation. Condensate is supplied by supply pumps back to steam generators. In this way, the steam and water secondary system is closed. The turbine condenser is cooled by cooling water that circulates in an open loop or closed loop (fitted with a cooling tower).

Boiling Water Reactors (BWRs) are much less commonly used in the nuclear power sector than PWRs (they account for 21% of all power reactors in operation today). The design of BWRs is basically similar to the design of PWRs: the core is enclosed in a pressure vessel, and fuel assemblies are built in a similar way. However, operating parameters of the reactor are much lower (pressure: 7 MPa, steam temperature at outlet: up to 290°C), and they are typical for the parameters of the secondary loop in PWRs. As a result, unlike in the PWRs, water boils and evaporates inside the reactor (see the figures presented above). Steam is generated in the reactor, and not in heat exchangers (steam generators) – as in the case of PWRs. In addition, there is no pressuriser in the BWR cooling system. But the electricity generation process itself is essentially the same as in any nuclear power plant using PWR units.

PGE S.A., the company that will invest in the first nuclear power plants in Poland, has received offers for two types of Generation III+ nuclear power units fitted with PWRs (EPR and AP 1000), and one offer for a BWR unit (ESBWR). All these units will ensure a high level of nuclear safety.

- EPR (European Pressurized Reactor), designed by a French company AREVA NP in co-operation with the German company Siemens KWU, represents the so-called "evolutionary line" in the development of nuclear power reactors.

  EPRs offer a number of solutions that ensure safety not only in normal operating conditions and during design–basis accidents, but also contain the effects of serious breakdowns – including those that involve the complete meltdown of the nuclear core (in particular a solid two-layer concrete containment fitted with a 'core catcher' to prevent damage of the containment structure by the molten core). In addition, the design took account of any potential external threats, both natural and man-caused, including plane crashes (also of large passenger planes) or external explosions.

- The AP 1000 *(Advanced Passive)* reactor, designed by the US company Westinghouse Electric LLC (part of Toshiba Corporation), represents the so-called 'innovation line' in the development of nuclear power reactors.

  The AP 1000 is an upgraded reactor with built-in safety features that offers a wide range of passive safety solutions that use natural forces and phenomena (natural convection, gravity, spring force, and compressed gas pressure). The passive safety systems of the AP 1000 absorb heat from the reactor core and cool down the safety containment for as long as 3 days without any AC power supply or operator's involvement.

- The ESBWR *(Economic and Simplified Boiling Water Reactor)*, offered by GE Hitachi Nuclear Power Americas, is an innovative, economical, and simplified Generation III+ Boiling Water Reactor with natural convection in the core and passive nuclear safety features.

  Passive systems ensure cooling of the reactor and its containment. This ensures high level of nuclear safety. No action from the operator and no A/C power supply are needed for 3 days after a breakdown.

Principles of nuclear safety

From the very beginnings of nuclear power plants, people were aware of the potential threats and actions were taken to protect the personnel and the society from the effects of a possible breakdown. The basic assumption is that nuclear risks should be smaller than risks associated with any other electricity production methods.

Defence in depth

The objective of defence in depth is to compensate for potential human errors and component failures. A system of defence in depth is based on the assumption that we cannot rely completely on any single element resulting from the design, maintenance, or operation of a nuclear power plant.

Defence in depth ensures that units with 'active' safety systems are redundant to ensure that safety functions are maintained even if one component is damaged. However, this strategy is not limited to the construction of additional redundant units. Defence in depth is structured in five levels of safety:

I. ***Level one –*** prevention of abnormal operation and system failures in a nuclear power plant. It is based on reliable and conservative design (high safety margins and careful selection of materials), as well as redundancy, independence, and diversification of systems and equipment critical for nuclear safety, and the high quality of construction, maintenance and operation of a nuclear power plant, in particular the culture of safety – adoption of a rule that safety always comes first.

II. ***Level two –*** control of abnormal operation and detection of failures to prevent incidents turning into breakdowns. This level involves the use of systems defined in safety analyses (i.e. normal systems in a nuclear power plant, such as power reduction system and normal reactor shutdown) and the optimum operational procedures to prevent or reduce damage caused by operational incidents.

III. ***Level three –*** control of accidents within the design basis in an unlikely case when certain operational incidents are not controlled at level two and evolve into a more serious accident. This level is based on the inherent safety features of a nuclear power plant and the designed (engineered) safety systems whose objective is to restore the controlled state first and then move on to a safe shutdown, and to ensure that at least one barrier that confines radioactive materials remains intact.

IV. ***Level four –*** mitigation of consequences of severe accidents (beyond design basis conditions) to confine the external releases of radioactive materials at the lowest level possible. The key objective at this level is to maintain the highest efficiency of the safety containment to confine the release of radioactive substances to the environment.

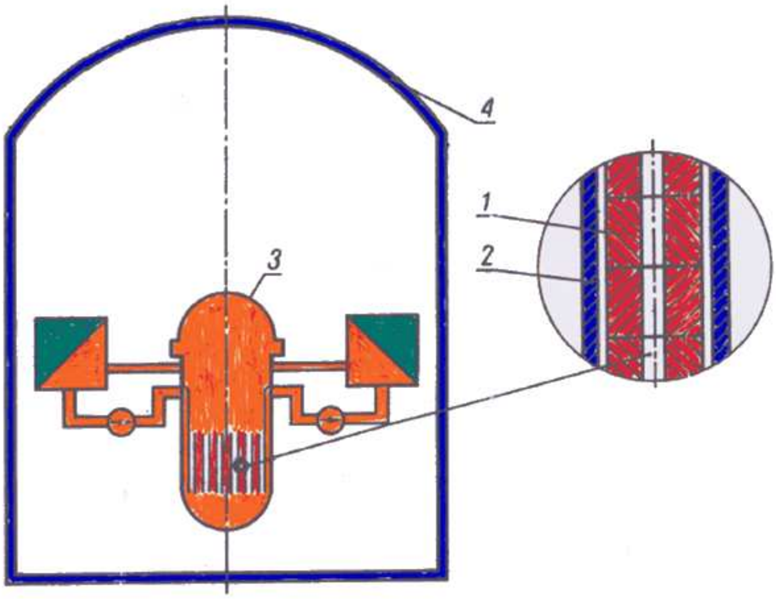
V. ***Level five –*** mitigation of the radiological consequences of significant external releases of radioactive substances that may result from an accident. It requires in particular a well-equipped emergency management centre and implementation of the effective on-site and off-site emergency response plans. At this level, off-site emergency response activities are necessary to reduce the exposure of people to radioactive materials, including administration of stable iodine pills, an order to stay at home or keep cattle indoors if pastures are contaminated, or temporary evacuation from the nearest vicinity of the nuclear power plant.

Natural safety features and safety systems of a nuclear power plant that are designed to contain the accident are upgraded continually, and reactors have become safer over decades. The key focus is now on the appropriate design of nuclear reactors, with built-in safety features based on natural phenomena such as gravity or natural convection.

Safe design of nuclear power plants

A system of barriers that contain the spread of radioactive substances in the event of an accident

The defence in depth principle is implemented in particular by using a series of physical barriers that confine radioactive substances in designated locations on site and prevent their uncontrolled release to the environment. These barriers are shown in the figure below.



Safety barriers: 1 - nuclear fuel material, 2 – fuel rod jacket, 3 – pressure limits of the reactor cooling system, 4 – safety containment.

The vast majority of radioactive isotopes (~99%) are trapped in nuclear fuel pellets inside fuel rods. Volatile products of the fission reaction (radioactive noble gases and aerosols) go through the gas gap between the fuel pellets and the fuel rod jacket and are stopped by the jacket (only a very small quantity goes through to the coolant that circulates in the primary loop).

Activity of cooling water in the primary loop is determined partially by volatile radioactive products from nuclear fuel going through micro-gaps in fuel rod jacket, and partially by activation of the coolant itself and any impurities contained therein or chemicals added to the coolant (radiation of neutrons in the reactor). The coolant undergoes continuous treatment. Any radioactive substances are also removed from the coolant.

The reactor and its entire primary loop are enclosed in a leak–proof safety containment designed for overpressure that may be created by rupture in the primary loop, which will cause a release of considerable amounts of radioactive substances (mainly from fuel released from damaged jackets), but also designed for external loads (seismic events, extreme weather conditions such as hurricanes, explosions, or plane crashes).

Considerable amounts of radioactive substances may be released from nuclear fuel as a result of a mechanical damage (direct effect of mechanical forces) or overheating (insufficient cooling may cause damage to all fuel rod jackets, defragmentation, and even melting of the fuel material).

To prevent or minimise damage to nuclear fuel caused by operational incidents or breakdowns, the following actions are needed:

- reliable and immediate shutdown of the reactor,
- reliable and effective release of after-heat generated in nuclear fuel after the shutdown.

In emergency situations, the safety of people and the environment – i.e. reduction of the uncontrolled releases of radioactive substances from the nuclear plant into the environment –

depends to a large extent on the integrity and tightness of the safety containment as well as its efficiency in the removal of radionuclides released from nuclear fuel and the cooling system.

Efficiency of the system of safety barriers was confirmed in practice when a breakdown occurred in nuclear unit no. 2 of a Pressurised Water Reactor (PWR) in the Three Mile Island nuclear power station, involving a meltdown of the nuclear core (1979, TMI-2, USA). Barriers 1 and 2 were lost, but the reactor vessel (barrier 3) and the safety containment (barrier 4) remained tight. It was the largest accident in a water reactor ever, but despite the damage to the reactor itself, its radiological effects were rather limited – nobody lost their life or health due to this accident (average off-site radiation doses reached 1% of the annual natural background radiation doses). We should note that the Three Mile Island reactor was a Generation II reactor with single safety containment, much weaker than the double containment design of the Generation III+ reactors offered to Poland.

Natural safety features and passive safety systems

A nuclear power plant design includes a number of features and systems based on the laws of nature, such as gravity, that ensure natural control and protection without any external energy source. The key feature is the internal stability of reactors cooled and moderated with water (including PWRs and BWRs that are the most common types of nuclear reactors used around the world today). This stability is based on the fact that after nuclear fission neutrons move very fast (fast neutrons), while the fission of uranium requires slow-moving neutrons (thermal neutrons). Water is used to slow neutrons down; in reactor technology, water is a 'moderator'. Fast neutrons collide with hydrogen nuclei and lose their kinetic energy. After repeated collisions they finally become thermal neutrons. The more water is used, the slower the neutrons will move and they become more capable of causing fission of uranium nuclei. On the other hand, a small portion of neutrons that collide with hydrogen is absorbed. Therefore, we cannot use too much water. The amounts of water and fuel are precisely calculated and adjusted to ensure that the neutron-slowing effect and the capacity of nuclear fission reaction are the highest at normal operating temperature. When water is heated and its density is reduced or – worse still – when water evaporates and its volume in the core is reduced, the neuron-slowing effect is lower, and instead of colliding with uranium nuclei neutrons will rather escape from the core and will be absorbed by the surrounding structural materials. As a result, the number of fission reactions in the core will drop and the nuclear fission chain reaction will stop. It is a critical feature that ensures stability of PWRs. It is the exact feature that was missing in Chernobyl.

Reactor safety system is another system that uses natural forces. It involves the use of neutron-absorbing rods. During normal operation of a PWR, neutron-absorbing rods are suspended over the core and kept in place by electromagnets. In the event of an electrical power failure or a breakdown signal from the safety system, voltage in electromagnets will drop and rods will fall automatically into the core under gravity to stop the reactor.

Emergency flushing of the core with cooling water if the primary loop is broken

If the primary loop is broken, cooling water escapes and the core is uncovered. If fuel rods are not cooled down, fuel temperature will increase and fuel would eventually melt down. Therefore, after the reactor is shut down, the first action is to inject cooling water into the reactor to make sure that the core remains immersed in water. Today's Generation II reactors and the so-called 'evolutionary' Generation III reactors are fitted with active and passive emergency core cooling systems. Active systems consist of three or four parallel sub-units with coolant tanks, pumps and valves, designed to ensure that any single unit is sufficient to immerse the core in water and cool it down effectively. On the other hand, passive systems perform their functions without any external source of electricity.

Absorption of excess heat in emergency situations based on natural convection

After–heat is generated in the reactor core after the shutdown of a nuclear reactor (as the name suggests) as a result of decay of radioactive radionuclides contained in nuclear fuel. After-heat in PWRs is absorbed in steam generators in the secondary loop where cooler water circulates. If primary loop pumps are switched off due to an accident, water in the reactor core will evaporate. If the flow of coolant is interrupted, steam will collect in the reactor vessel above the core and gradually push water out of the core. As a result, the core could be exposed and nuclear fuel damaged. To prevent this situation, designers of nuclear reactors locate the individual elements of the primary system in such a way as to make sure that the core is located well below steam generators, which ensures the flow of coolant from the core to steam generators in a natural convection system – which is sufficient to absorb after-heat.

Passive systems that ensure safety when the power supply is interrupted

If power supply from the power grid is interrupted, nuclear power plants may use their own back-up power generators powered by high-reliability Diesel engines. However, if these back-up units happen to fail too and power supply is interrupted for a number of days, active heat absorption systems cannot perform their functions without the supply of electricity. This situation is extremely unlikely, especially that in many cases nuclear power plants have a direct connection with an adjacent hydroelectric power plant that is able to supply electricity within a short time. However, this scenario is still taken into account when analysing possible emergency conditions.

If the power supply from all sources is interrupted, it may result in a core meltdown, melting of the reactor vessel, and release of molten fuel materials and structural materials outside of the vessel into the safety containment. Therefore, today's nuclear power plants are fitted with systems that will contain the effects of even such an unlikely serious accident. The general trend in the latest state-of-the-art reactors is to introduce the **highest possible number of passive safety systems** that require no signals to be triggered, no external power supply, and no operator involvement.

Principles of safety system design

- Resistance to a single damage

If certain safety functions cannot be guaranteed by using passive systems, high-reliability active safety systems are used. These systems are designed to perform their functions also when any one of their component parts is damaged due to some unforeseen events. Therefore, these components are usually redundant; in most nuclear power plants there are three or (in the most modern plants) even four parallel subsystems, each sufficient to perform all safety functions.

- Diversification of safeguards

Existence of two or more elements that ensure redundancy will prevent a single breakdown of one of these elements, but will not prevent a failure of the entire system due to a common cause that was not known at the time when the reactor was designed or that was considered improbable at that time. To protect the reactor from a loss of safety functions due to a common cause, redundant subcomponents of the safety systems are made of different elements, whenever possible, so that one event that caused a single breakdown cannot cause the simultaneous loss of all safety subsystems.

- Spatial separation

Safety systems are separated physically to make sure that an event such as fire will not cause a loss of two or more subsystems at the same time. In state-of-the-art nuclear power plants, each of the four safety subsystems is located in a different section of the reactor building, separated physically from other sections. In this way, even a plane crash will not cause a loss of more than one safety subsystem. Control cables and power cables of safety systems are laid separately from any cables connected to non-safety systems. In addition, control cables are laid in troughs that are separated from troughs that contain power cables.

- Resistance to fire, flooding, seismic shock, and ambient conditions

Neither redundancy nor diversification of safety-critical elements will be sufficient to ensure safety unless these elements are resistant to seismic shock and the expected temperature, pressure and humidity conditions. In particular, fires are hazardous as they may cause a loss of a number of safety elements within their reach. Therefore, when designing safety-critical systems in a nuclear power plant, a fire risk analysis is performed for any locations where these systems are installed, and safeguards are introduced to eliminate or reduce the risk of fire – for instance, replacement of oil with water as a lubricant for pump bearings. If the risk of fire is not eliminated, its potential reach and duration is analysed and certain measures are introduced to prevent the spread of fire, including fire detection and fire fighting systems. A systematic fire risk analysis must be conducted for all premises in the nuclear power plant, and all necessary safeguards must be introduced, including modification of building plans and specifications.

The same applies to the risk of flooding. If there is a possibility that safety-critical equipment may be flooded, a waterproof version should be always used. Any systems located inside the safety containment, where water is sprinkled to reduce the pressure of vapour after a rupture in the primary loop, must be resistant to steam and water under pressure equal to the maximum pressure level in emergency conditions.

All safety-critical systems must be resistant to maximum seismic shock levels expected for a given nuclear power plant.

Safety culture

In nuclear power plants, the culture of safety governs all activities and co-operation between all persons and organisations working in the nuclear power industry. The overriding principle is that **nuclear safety and radiological protection are superior** to any other aspect of operation of a nuclear power plant – especially its production goals.

Responsibility for nuclear safety must be clearly defined. Both the management and personnel of a nuclear power plant must be sufficiently trained to make sure they are aware of the importance of nuclear safety. Employees are encouraged to learn from their mistakes and treat errors made by others as lessons learned.

1.7 Analysis and evaluation of the impact of radioactive emissions from nuclear power plants

General information

Chapter 7 discusses the feature of nuclear power plants that is most critical from the perspective of the environmental impact of the nuclear power sector – namely, emissions of radioactive substances and radiation doses generated by nuclear power plants during normal operations, any possible breakdowns, and nuclear decommissioning of the facility. This chapter is structured in a way that reflects the logical progression of a possible chain of events. First, we present historical data on the emissions of radionuclides from nuclear power plants that have been in operation for the past half-decade and are similar to nuclear power plants offered to Poland. Based on the knowledge of modifications introduced to the latest cutting-edge reactors (Generation III or III+), the possible release of radioactive substances from nuclear power plants in Poland was evaluated. To this end, we defined the amount of radioactive products of nuclear fission reactions in the reactor and their potential release, i.e. emissions outside of the safety containment – for normal operations, design-basis accidents, and the most serious possible accidents that can happen once in millions of years. As doses of radioactive materials that humans and the environment are exposed to depend not only on the level of emissions, but also on the conditions determining the spread of isotopes in the atmosphere, the next part of this Chapter discusses the methods of assessment of weather conditions for the long-term operation of nuclear power plants (both average representative conditions during the year and emergency conditions). Based on the emissions and conditions determining their spread in the atmosphere, we evaluated the expected doses of radioactive substances from nuclear power plants during normal operation and in a state of emergency.

As the specific reactor type that will be used in nuclear power plants in Poland has not been selected yet, the study includes an analysis of the environmental impacts of three reactors of the latest generation, representing the solutions expected to satisfy the nuclear safety and radiological protection requirements defined in the most recent draft Atomic Energy Act and the related regulations of the Polish Council of Ministers.

On the basis of the safety features of these representative reactors, we defined the restricted-use area outside of which early evacuation or permanent resettlement of humans is not required (even after a serious accident), and the possible intervention will be easy to introduce and will not interfere with the living conditions of the local population in the long term (for instance, administration of stable iodine pills). We also defined the range of the zone outside of which no intervention is planned. These evaluations assumed the typical weather conditions determining the spread of radioactive substances in the atmosphere. As these conditions are different in each location, the reference weather conditions must be defined and precise calculations must be performed for the selected location. However, the general findings of these assessments indicate that the radius of a restricted–use area will reach about 800 meters, and radius of the emergency planning zone – about 3 km around the reactor. These figures were applied to the suggested locations and used to prove that the most preferred locations will need no arrangements with the local communities and authorities of the neighbouring countries as to the planned interventions.

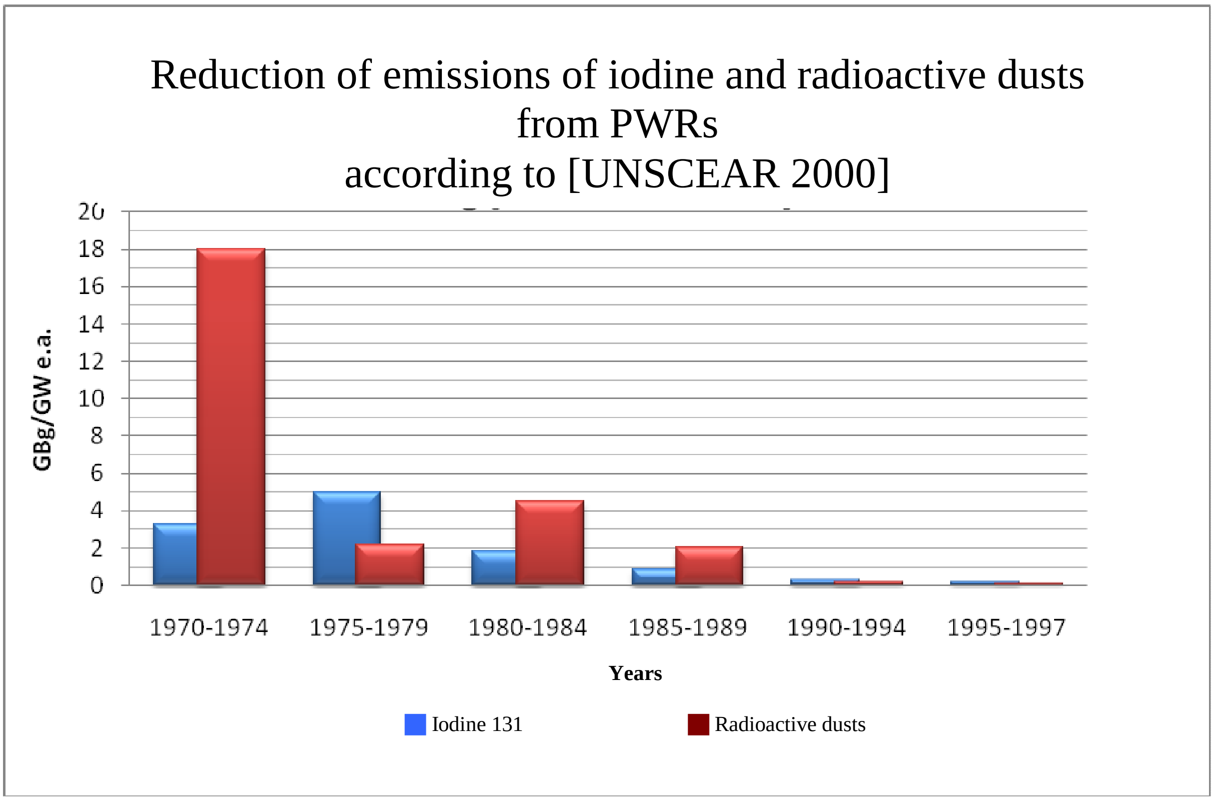
The subsequent part of this Chapter discusses the environmental impacts of nuclear decommissioning operations, as well as the potential health effects of radiation (assuming radiation doses defined for the entire life cycle of the nuclear power plant).

The general conclusion is as follows: radiation from a nuclear power plant does not pose any threat during its normal operation or design-basis accidents. Even in the case of more serious accidents that can occur once in millions of years, the risk is limited to the restricted-use area. Outside of this area, no interventions are needed after design-basis breakdowns, and after serious accidents they will be limited to actions that will not interfere with the living conditions of the local population in the long term, such as administration of stable iodine pills, within a small distance around the nuclear power plant (estimated at about 3 kilometers, depending on the local weather conditions and type of reactor).

Analysis of radioactive emission levels

Emissions of fission products during normal operation of nuclear power plants have been decreasing steadily as plant introduce state-of-the-art technologies and methods of work that keep the exposure to radioactive substances as low as reasonably possible. This trend is presented in Fig. 7.1 showing the drop in emissions of iodine and radioactive dusts from PWRs. Of the reactors proposed for Poland, two are Pressurised Water Reactors that use the experience gained during the last half-decade of their operation. They represent the EPR range (Evolutionary Pressurized Reactor) and

AP1000 – (Advanced Passive Reactor). Assessments based on the analysis of design modifications in the EPR (representing Generation III reactors) indicate that emissions from this reactor during normal operation are negligibly low.



Reduction of iodine and radioactive dusts emissions from PWRs – data from the UNSCEAR report

Emissions from PWRs are lower than emissions from BWRs, because the entire primary loop with the coolant (that contains radioactive substances and is activated when flowing through the core) is located inside a solid and tight safety containment. Outside the containment there is a turbine driven by a steam loop (secondary system) that collects heat from the primary system through walls of heat exchange tubes in steam generators and that does not contain any radioactive substances and poses no threat of radiation. In BWRs, steam generated directly in the core goes into the turbine. This steam contains radioactive substances and its releases (for instance if safety valves are opened) involve the release of radioactive substances. If the steam pipe is broken outside of the containment, iodine and other fission products may be released to the environment.

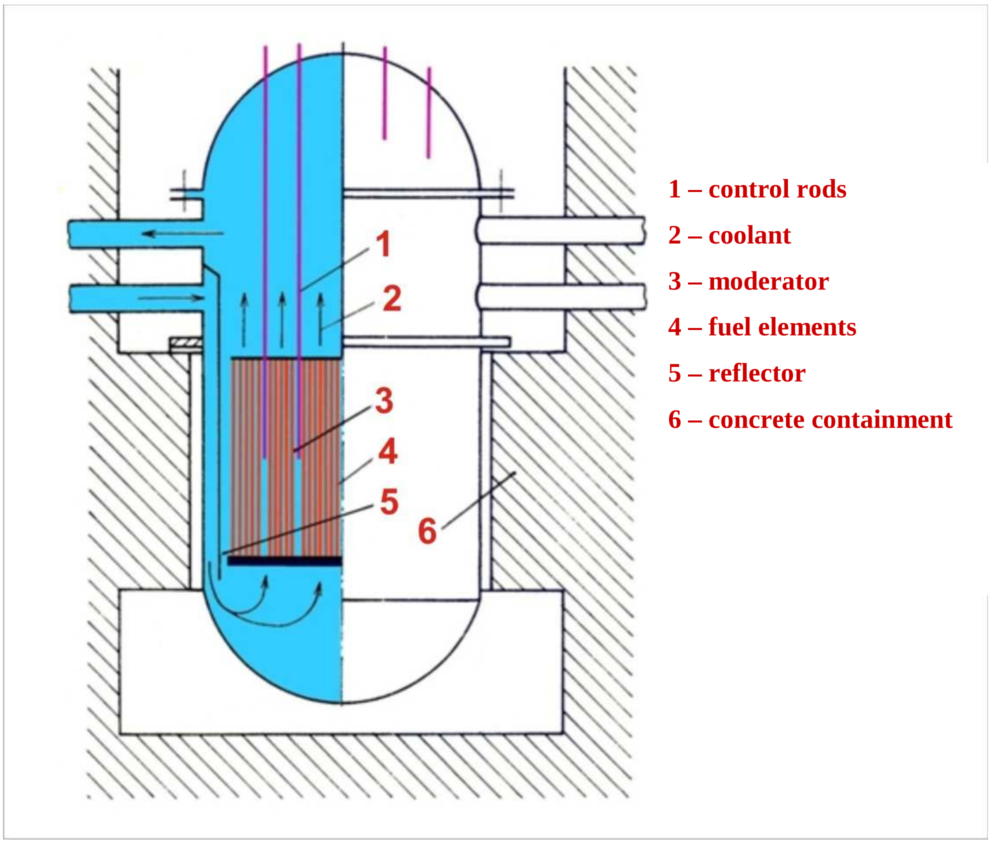
Given these differences, emissions generated during normal operation and in emergency conditions should be conducted separately for PWRs and BWRs. It turned out that during normal operation all emissions are low. Advanced technical measures used in Generation III reactors, including:

- consistent introduction of redundant safety systems,
- designing safety systems that are mutually independent, diversified, spatially and physically separated, and resistant to any potential emergency conditions in their environment,

combined with the consistent upgrading of the methods of operation in emergency situations ensure the high resistance to breakdowns and effective reduction of emissions if a breakdown occurs nevertheless. The weak link of BWRs is the possible rupture in the steam loop, which leads to significant releases of radioactive materials. On the other hand, both EPR and AP1000 are characterised by very low emissions after design-basis accidents.

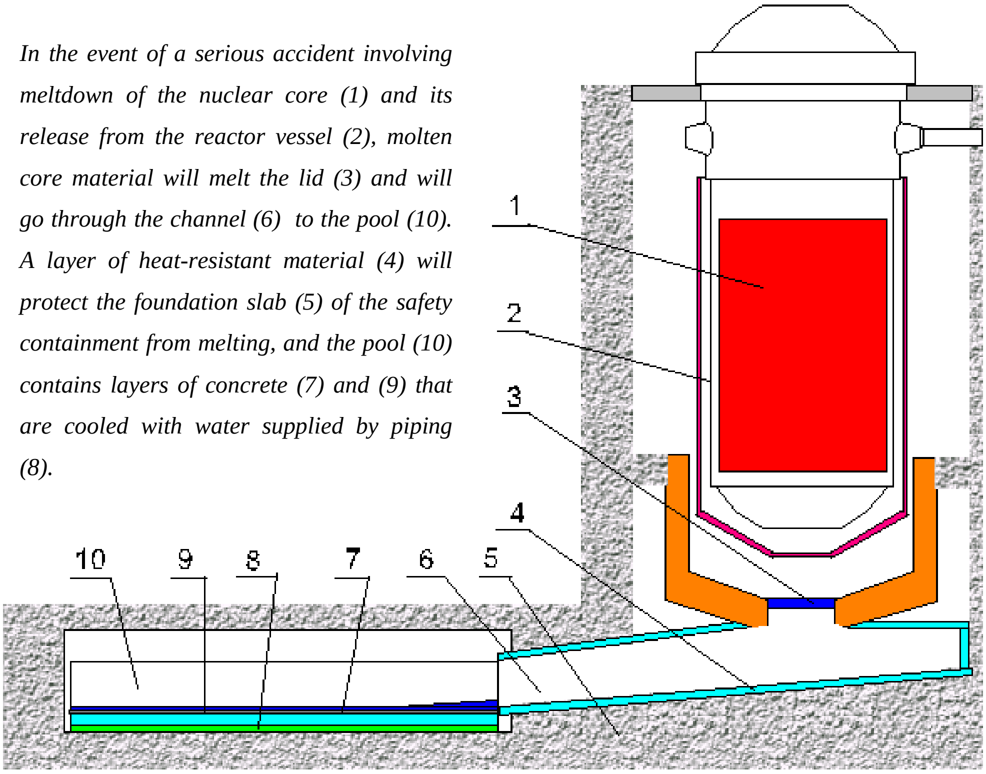
The probability of serious accidents and the related radioactive emissions is also low both for EPR / AP1000 and the ESBWR boiling water reactor (although threats are reduced by different means). All reactors have a solid safety containment; in EPRs, it will resist even the impact of the largest passenger airplane crashing down. In addition, EPR plants have four safety systems located in four separate buildings as an additional safeguard against an external attack. The fundamental feature of Generation III reactors is that their safety systems assume a core meltdown as the starting point, regardless of the very low probability of any accident that causes a core meltdown, and that reactor features and technical measures will protect people from this hypothetical threat.

All reactor designs include safeguards against early and sudden damage of the safety containment, for instance due to an explosion of hydrogen generated at high temperatures caused by the chemical reaction between water vapour and zirconium. A number of other systems ensure the reliable absorption of heat from the reactor and its safety containment. In the AP1000, the shaft where the reactor is located may be flooded with water (in the event of a serious accident) to ensure that the reactor vessel is cooled down from the outside and to prevent any puncture in the vessel caused by the hot core. In the EPRs and ESBWRs, this type of cooling would be insufficient as their capacity is higher. Therefore, a molten core catcher was introduced – a pool installed under the reactor vessel where the molten core will leak in the event of a breakdown and spread over a large surface of liquid (ensuring effective cooling of the molten layer of core materials).



Absorption of heat in the case of a serious accident in the AP1000 reactor – from the molten core through reactor vessel to water inside the reactor shaft.

In the event of a serious accident involving meltdown of the nuclear core (1) and its release from the reactor vessel (2), molten core material will melt the lid (3) and will go through the channel (6) to the pool (10). A layer of heat-resistant material (4) will protect the foundation slab (5) of the safety containment from melting, and the pool (10) contains layers of concrete (7) and (9) that are cooled with water supplied by piping (8).



Core catcher in the EPR

These methods were tested and approved by the nuclear regulatory authorities in the leading countries such as the USA, France, the UK, Finland, Japan, Korea, China, and Russia. Their effectiveness is beyond any doubt. With these systems we may expect that after a serious accident (involving damage of the nuclear core), inhabitants of the zone outside of the restricted-use area will not be affected.

Assessment of the direct and indirect routes of radiological exposure in emergency conditions

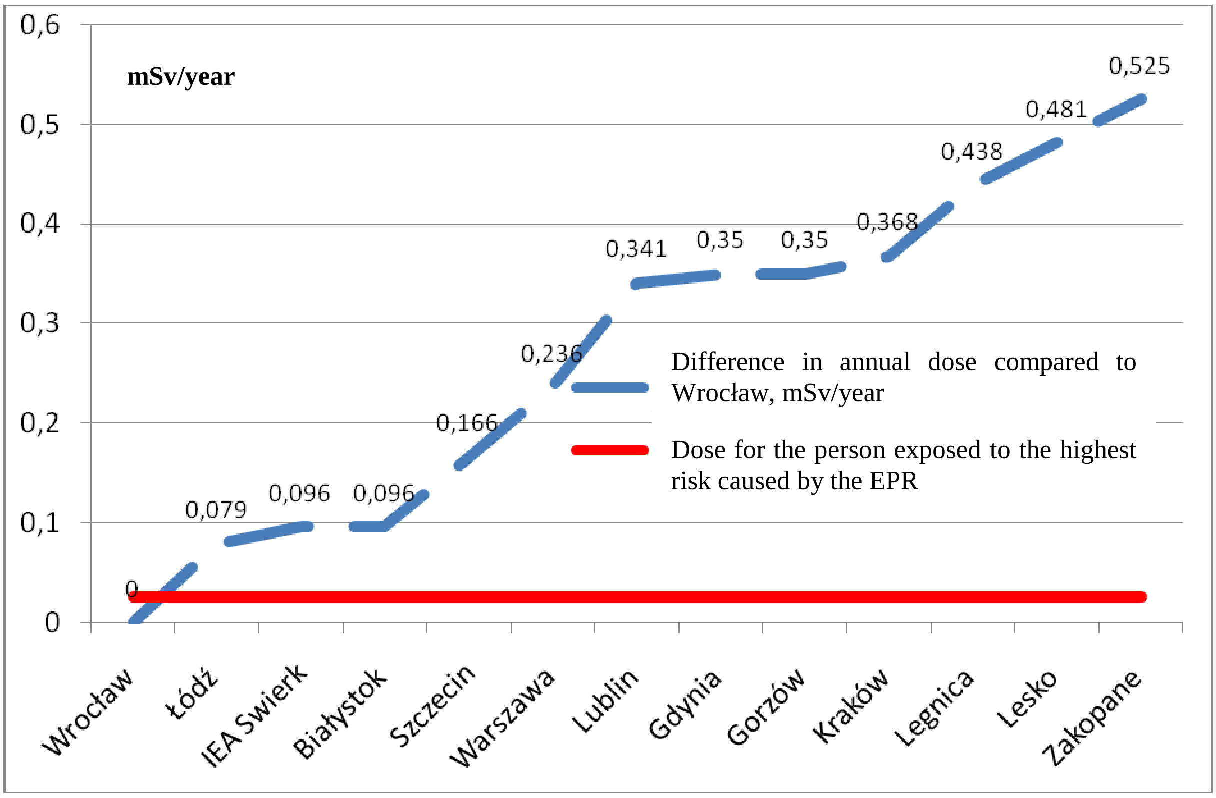
If radioactive substances are released from the nuclear power plant to the atmosphere, radioactive exposure will depend on the atmospheric dispersion factor. This factor depends of the atmospheric stability class, wind velocity, and distance from the emission source. The most adverse weather conditions are connected with low dispersion, i.e. high stability of the atmosphere and low wind velocity. As weather characteristics are different for each location, the report uses calculations for a single representative type of atmospheric dispersion selected in accordance with the guidance from the US Nuclear Regulatory Commission (US NRC). These dispersion conditions are better than assumed in safety analyses conducted by manufacturers of reactors. It is rather obvious, since manufacturers try to prove that their reactors can be installed even in the most disadvantageous locations and will still meet the applicable safety criteria. It is very likely that after the specific location is selected, it will probably turn out that radiation doses defined by the manufacturers can be reduced.

Summary of the impact of radioactive emissions from nuclear power plants during normal operation

Calculation of doses of radioactive substances emitted during normal operation of the EPR indicates that these doses are very small. If we consider the input from atmospheric emissions, deposits on fields and the contaminated food produced on land, as well as fish exposed to radiation coming from nuclear power plants, inhabitants of highest-risk areas within 500 m around the reactor will be exposed to radioactive doses amounting to about 26 microsieverts, i.e. much LESS than the difference in annual doses between average towns and cities in Poland. For instance, the average dose of external radiation in Kraków is higher by 390 microsieverts than in Wrocław. It means that an inhabitant of Wrocław who decides to move to Kraków will be exposed to an additional dose of radiation 10 times higher than they would be exposed to in Wrocław if a nuclear power plant was built in front of their house with the fence of the nuclear facility right in front of their window.

The comparison of maximum doses of radiation from the EPR and differences in doses between towns and cities in Poland is presented below.

Still, nobody in their right mind would shy away from going to Kraków for fear of higher radiation. By the same token, we are not afraid of going to Zakopane, where radiation levels are even higher. We may therefore conclude with certainty that the low additional radiation in the immediate vicinity of a nuclear power plant during its normal operation is not a problem for the ecosystem and for human health.



Comparison of external radiation doses in various cities and towns in Poland and the additional dose of radiation that a person could be exposed to through all routes of exposure in highest-risk areas in the vicinity of the EPR.

Summary of impacts in transient and emergency conditions

In the event of design-basis accidents that are rare or very rare (down to failures that occur every 100,000 years), doses of radiation from the EPR that a person in the highest-risk area may be exposed to are very low. For breakdowns inside the safety containment, these doses will reach about 1 mSv per person, and for accidents during the unloading of nuclear fuel and involving the release of radioactive materials outside the safety containment this dose will reach 5.5 mSv (assuming the unfavourable atmospheric dispersion factor). For atmospheric dispersion factors expected in the suggested locations in Poland, doses of radiation caused by all design-basis accidents in the EPR will not exceed 5 mSv even at the distance of 800 m from the reactor.

The situation is worse for ESBWRs. If the steam piping is broken outside of the safety containment (which is classified as a design–basis condition) and if we assume a worst-case scenario for the atmospheric dispersion factor, the dose of radiation at the limits of the restricted-use area will reach 126 mSv. This dose will be lower in better weather conditions, but the restricted-use area needs to be much larger than 800 m to make sure that the dose outside of this area is within the limits assumed in the current draft of the Act.

Summary of impacts caused by serious accidents

In the event of a serious breakdown, emissions from Generation III reactors are limited thanks to the technical solutions and natural safety features, so that a long-term or severe exposure of the local population is not possible even for the core meltdown scenario assumed in the analysis. Special safety requirements adopted by the European power utilities (known as EUR, European Utility Requirements) assume that reactors must be safe not only during normal operation and design–basis failures, but also during serious accidents involving the nuclear core meltdown. The same requirements were introduced to the proposed provisions of the Polish Atomic Energy Act and the related regulations of the Polish Council of Ministers. Reactors offered to Poland must conform to these requirements.

Thorough verification of all safety features is only possible after completion of an analysis of the reactor’s documentation by the nuclear regulatory authorities. However, for the purposes of this study it was assumed that the results of analyses of three reactor designs by the EUR Committee and the nuclear regulatory authorities in the USA, Finland, France, China and the UK will be sufficient. AP1000 and ESBWR reactors offer considerable reduction of the frequency of serious accidents and have special solutions to prevent early and significant releases of radioactive materials after the reactor core melts. They meet the requirements concerning reduction of the likelihood of accidents and reduction of the hazard in the event that a serious accident does occur despite all of the preventive measures.

In general, we can expect that reactors built in Poland will meet the requirements of the Polish standards proving that in the event of a serious accident that involves the nuclear core meltdown, there is no need to take early and long-term intervention (such as evacuation or permanent resettlement) outside of the restricted-use area whose radius is currently defined at about 800 m (depending on the actual local weather conditions and the type of reactor). Mitigation measures with limited and medium-term scope, including administration of stable iodine pills, may be required after a serious accident within the LPZ (low population zone) – about 3 km around the reactor according to the EUR requirements (also depending on the local weather conditions and the reactor type).

The following table presents a summary of the parameters of radiological impact on humans and the environment for the nuclear power plant proposed for Poland, with an envelope including the results for Generation III reactors, taking into account the standards proposed for Poland.

Parameters of radiological impact on humans and the environment for the nuclear power plant proposed for Poland defined for the limits of a restricted-use area.

PARAMETER	RESULT IN ANALYSES PREFORMED FOR:			FOR THE NUCLEAR PLANT IN POLAND
	EPR	AP1000	ESBWR	
Atmospheric dispersion factor χ/Q for the distance of 800 m from the nuclear power plant and for the time of 2 h, s/m^3	$1*10^{-3}$	$5.1*10^{-4}$	$2*10^{-3}$	$2.5*10^{-4}$
Radius of the restricted-use area, m	800	800	800	800
Annual dose during normal operation, mSv	0.025 mSv,	0.121 mSv,	0.012 mSv,	0.30 mSv, 800

		500 m from the plant	800 m from the plant	800 m from the plant	m from the plant
Dose after an accident without core meltdown, 800 m from the plant, mSv	at χ/Q assumed in reports presented by suppliers of reactors	5	22	126	10
	at χ/Q assumed for the nuclear plant in Poland	1.4	10.8	15.8	
Dose after a serious accident with core meltdown, for 2 hours, for the assumed χ/Q, mSv	at χ/Q assumed in reports presented by suppliers of reactors	122	246	130	100
	at χ/Q assumed for the nuclear plant in Poland	30.5	120.6	16.3	
χ/Q for the boundary of a low population zone LPZ (2,400 m) s/m^3					
0-2 h		$1.75*10^{-4}$	$2.2*10^{-4}$	$1.9*10^{-4}$	Data must be defined for the specific location, based on the annual cycle of meteorological measurements
2-8 h		$1.35*10^{-4}$	$2.2*10^{-4}$	$1.9*10^{-4}$	
8-24 h		$1.00*10^{-4}$	$1.6*10^{-4}$	$1.4*10^{-4}$	
24-96 h		$0.54*10^{-4}$	$1.0*10^{-4}$	$0.75*10^{-4}$	
96-720 h		$0.22*10^{-4}$	$0.8*10^{-4}$	$0.3*10^{-4}$	
χ/Q for the boundary of a low population zone LPZ s/m^3, arithmetic average for 30 days		$2.63*10^{-5}$	$8.53*10^{-5}$	$3.87*10^{-5}$	
Dose after a serious accident with core meltdown, for 30 days, for χ/Q for the boundary of a low population zone LPZ, mSv		111	234	353	
Frequency of serious accidents involving high releases outside of the safety containment		Less than 10^{-6} /reactor-year	$6*10^{-8}$ /reactor-year	Less than 10^{-8} /reactor-year	Less than 10^{-6} /reactor-year

Nuclear decommissioning of the EPR – impact on the ecosystem

Chapter 7 also analyses the possible course of action and effects of the nuclear decommissioning procedure for a Generation III reactor such as the EPR. Experience in decommissioning of nuclear power plants and other nuclear installations to date indicates that the nuclear sector has the necessary skills and technical measures to implement this process effectively. Decommissioning of a nuclear power plant with full-capacity reactors (900 MWe) in a number of different countries (the USA, Japan, Germany) has shown that the costs and time frames of this process are within the design, and radiological risks for the personnel and the surrounding area are small, comparable to the risks associated with normal operation of the nuclear power plant.

In the case of Generation III nuclear power plants, their designs included the nuclear decommissioning requirements from the very start. It was manifested in:

– optimum design of the geometry of all systems – to ensure easy dismantling,

– selection of materials – to reduce the activation of materials and eliminate the collection of radioactive substances,

– introduction of local protective shields - to reduce the personnel's exposure during decommissioning works.

Detailed analysis of the expected decommissioning operations for the EPR shows that this reactor was well designed and ensures the highest possible reduction of the radiation exposure for humans and the ecosystem.

Flamanville nuclear power plant - case study summary

The case study of the impact of the new EPR unit no. 3 in the Flamanville nuclear power plant in France on human health and the ecosystem has shown that:

- very small emissions of non-radioactive gases will have no detectable impact on the quality of air in the area of Flamanville,
- operation of the EPR will have no significant impact on the current radioecological conditions around the nuclear power plant,
- nuclear waste will be reprocessed and stored in the power plant building to make sure that containers will not leave the controlled area without prior control and approval,
- radioactive waste will be transported by rail or by road only in final containers that will meet the requirements defined by the nuclear regulatory authorities,
- methods of transport of containers with radioactive waste will meet all the applicable requirements for transport by rail or in trucks.

Summary of the impact of small doses of radiation on living organisms

Long–term studies conducted in many parts of the world and among different populations have proven beyond any doubt that small doses of radiation – comparable to natural background radiation – have no negative impact on human health, including adults, children, and the offspring of persons exposed to radiation.

Still, up until recently, comparative analyses would assume that every dose of radiation carries a risk that is proportional to the dose. All analyses performed by 2005, the results of which are quoted in this study, were based on this assumption.

The leading specialists in health protection call for additional studies and development of models that would explain the impact of small doses of radiation on human health. Studies are underway, but in the meantime everyone agrees that small doses of radiation either have no negative impact at all or these impacts are undetectable even when studying the largest populations. On the other hand, many renowned scientists and highly reputed institutions claim that the majority of results even suggest a positive effect of small doses of radiation.

1.8 Analysis and evaluation of other expected significant impacts related to the operation of nuclear power plants

Impacts at the Programme implementation stage

Planned activities related to the implementation of the Polish Nuclear Programme will have an insignificant impact compared to the construction and operation phases, but their effects will be long-term (until 2022) and multi-dimensional. At the first stage of the Programme, the appropriate bodies will be set up and the legal framework will be established for the development the nuclear power sector in Poland. These actions will have long-term positive effects, as they will pave the way for the development of a new energy sector in Poland. Then, actions will be taken to train the Polish specialists in nuclear power generation, and to educate the Polish society based on information and education campaigns. The impact of these actions on people will be positive: the environmental awareness and knowledge of the Polish citizens will improve, and the knowledge of specialists and experts in the field will help improve the technologies currently used in Poland. In the long term, these actions may prove very useful in the development of innovative technologies in the country.

Impacts at the construction stage

Impacts at the stage of construction of nuclear power plants are significant, as construction works usually last for about 6–7 years.

<u>Impact on water</u>

In the construction phase, waters are mainly exposed to impacts caused by earthworks conducted on site, especially in areas where ground waters are not separated from the surface by an impermeable layer. However, the very basic safeguards during normal construction works will eliminate the risk of groundwater contamination with substances from the surface of the construction site.

During the first commissioning and tests of the nuclear reactor, the possible emissions of chemicals to water are analysed. The actual amounts of these chemicals depend on the type of cooling systems installed and the local conditions for the intake and discharge of water, and they should be specified in detail for a given location of the project.

<u>Impact on the air</u>

In the construction phase, dusts may be emitted to the atmosphere as a result of earthworks, transport of soil and building materials, production of concrete, or storage of loose materials. However, there are effective methods to prevent the excessive production of dust, for instance by sprinkling water on roads and worksites (where cutting or crushing of building materials takes place). The quantity of dusts emitted to air may be evaluated only during the environmental impact assessment for the construction of a nuclear power plant in a specific location. The same applies to emissions of exhaust gases from machinery and vehicles. Their impact will be evaluated only after the specific location of the project and transport routes leading to the construction site have been defined.

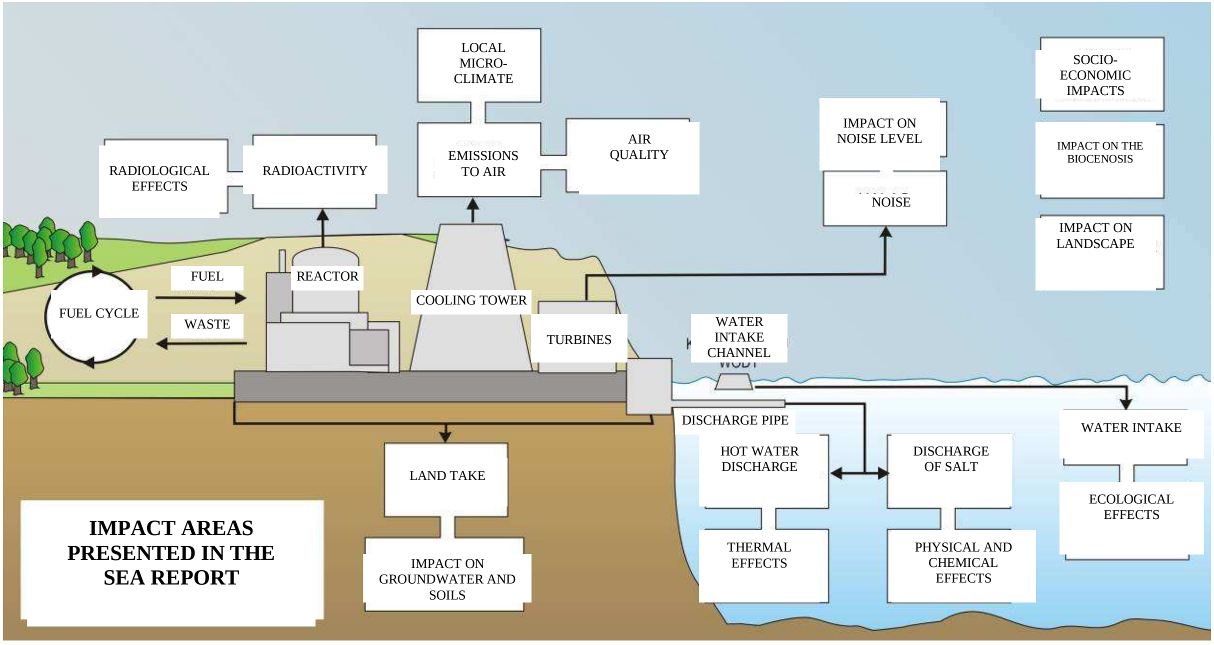
In the testing phase during the pre-commissioning of the entire installation, it will be heated up to high temperatures for the first time. As a result, chemical substances may be released to the atmosphere. Even if we assume the worst-case scenario, the impact of these emissions on the air will be insignificant, and precise models are not necessary.

<u>Impact on the Earth's surface</u>

The impact of the construction of power generation facilities and the related transmission infrastructure will consist mainly in the stripping of topsoil and modification of the ground structure in the immediate vicinity of the planned investment. Impacts of this type may also be observed in the location of the temporary storage of building materials and structural elements. The potential impacts also include the pollution of soil with petroleum products that mat be released into the ground due to leakage or breakdowns of mechanical vehicles. However, impacts of this type will occur only in the direct vicinity of the project and, given their limited scale, do not require any recultivation works as a rule.

Impacts at the stage of normal operation of the nuclear power plant

The following Figure presents the impacts of a nuclear power plant on individual elements of the environment in the operational phase. This Chapter discusses these impacts one by one, with the exception of radiological impacts – they have been discussed earlier. The summary presents key elements of the entire scope of impacts. Certain less significant aspects are only recaptured in the Table below to avoid repetitions.



Impacts related to the fuel cycle

The fuel cycle includes the supply of raw materials to the nuclear power plant (extraction, processing, and enrichment of uranium, production of fuel elements, and transport), use of fuel to produce electricity, and management of spent fuel (reprocessing, including recycling, transport, neutralisation, and deposition).

The analysis conducted as part of the SEA Report indicates that resources of uranium currently available in Poland are scarce, and many years of exploration and prospecting works will be required to find new uranium deposits (if any). Therefore, the best option is to import fuel from abroad. The indentified worldwide resources of uranium extracted at a price lower than $130/kg amount to 5.5 million tonnes. Known resources of uranium ore extracted at about $130-260/kgU amount to 0.9 million tonnes. The resulting 6.4 million tonnes of uranium ore will satisfy the demand (at the current level of production of 61 thousand tonnes of uranium per year) for more than 100 years. With the introduction of breeder reactors and fuel recycling technologies that considerably increase the energy efficiency of nuclear fuel, the same resources will suffice for several thousand years (at the current level of electricity production). Given the availability of global uranium deposits (including deposits that have not been documented yet), it would be unreasonable to search for uranium ore in Poland. However, we should highlight the fact that hundreds of thousands tonnes of phosphorites are processed in Poland. Uranium contained in phosphorites forms an unwanted component of phosphates. It seems worthwhile to use this source of uranium – it will offer about 50 tonnes of uranium per year and will have a positive environmental impact.

Mining activities involving the extraction and processing of uranium ore have significant impacts on the environment. These impacts depend on the type of uranium deposit, parameters of the surrounding area, and the adopted mining technology. As the processing of uranium ore involves a chemical separation of this element, it may lead to migration of radioactive isotopes deposited in uranium ore during millions of years as a result of uranium decay. Migration of these isotopes may be reduced by using the optimum extraction and processing technologies. The processing of uranium ore produces waste that may contain radioactive isotopes deposited in uranium ore during millions of years as a result of uranium decay. We must note that these activities will not lead to any increase in the amount of radioactive elements in the lithosphere, and the only risk is related to their relocation or easier migration to water and air. A properly designed radioactive waste depository (using mining pits whenever possible) will ensure permanent neutralisation of natural radioactive isotopes in a manner that is not much different from their original state. Migration of radium, radon, and other products of uranium decay is a natural process, and radium and radon waters are commonly found in the lithosphere and sometimes used for medical purposes. Uranium mining and pre-processing takes place in areas where the quantities of radioactive elements are naturally higher, and their negative impact on the environment should not be exaggerated. In addition, these impacts will occur outside of Poland.

A nuclear reactor in a power generating unit with the capacity of about 1000 MW will use less than 20 tonnes of nuclear fuel per year - equal to one freight wagon per year (as a comparison, about 3 million tonnes of coal per year must be burned in a coal-fired power plant with the same capacity – which equals about 160 carriages). The fuel cycle in a nuclear reactor, i.e. the period of fuel burn-up followed by its replacement, lasts for 12 to 24 months, and fuel assemblies will remain in the core for about 3 fuel cycles (i.e. 3 to 5 years). The reactor is filled with new fuel only partially in carefully planned configurations (the reactor core contains several hundreds of fuel assemblies of various degree of enrichment and burn-up) to ensure the most efficient use of nuclear fuel. Fuel cycles must be planned in advance, based on the analysis of long–term electricity production plans. These plans are a source of data necessary to place orders for nuclear fuel. Under the Polish Nuclear Programme, nuclear fuel will not be produced in Poland. Ready-for-use fuel assemblies will be purchased from global producers of nuclear fuel. Suppliers of the specific types of reactors are the most obvious and likely suppliers of nuclear fuel, but it may be ordered from another supplier, too. If need be, fresh fuel can be kept in store in a nuclear power plant for many years (given the low demand for nuclear fuel in terms of its quantity). Fresh fuel is transported (by sea, rail, or road) in special containers that protect fuel from damage, also in the case of accidents. Ionising radiation emitted by fresh uranium fuel is insignificantly small, so no radiation shields are necessary.

Spent fuel removed from the reactor is placed in a water pool, where it stays for at least 3 years (usually 7-10 years). During this time, it is cooled down and de-activated by tens of per cent. If spent fuel is not reprocessed, it is moved to the interim storage facility (usually located on site) where it can be stored for additional 40-50 years. Next, spent nuclear fuel is deposited in geological formations. Spent fuel removed from the reactor is highly radioactive and emits heat generated as a result of radioactive decay. After about 4 years, the activity of fission products contained in spent nuclear fuel declines by 4 times. After about 300 years, the activity of fission products declines by 1000 times and spent nuclear fuel becomes practically harmless. Spent nuclear fuel removed every year from a typical large reactor with the capacity of 1000 MWe (in the amount of about 30 tonnes) contains about 300 kg of fissile isotopes that can be recovered by reprocessing and reused in reactors. If fuel is used only once in a thermal reactor, the energy-generating potential of fuel materials is utilised to a very limited extent. If fuel is reprocessed and recycled, its energy-generating potential is increased – we can achieve approx. 30% savings of uranium and reduce the waste volume (by about 5 times) and waste radiotoxicity (by about 10 times). Spent nuclear fuel is transported in special containers that ensure protection from radiation and absorption of heat, meeting the strict safety requirements.

Studies of radioactive waste management in Poland are currently underway. Works are co-ordinated by the Team responsible for the development of the National Plan for Radioactive Waste and Spent

Nuclear Fuel Management Analyses conducted by the Team will be used as a basis to formulate recommendations as to the methods of management of spent nuclear fuel (whether it will be reprocessed and deposited in the country or partially removed abroad). A deep underground depository for highly radioactive waste and spent nuclear fuel will be needed about 30-40 years after the first nuclear power plant is put into operation in Poland – i.e. not earlier than in about 2050. Until then, spent nuclear fuel (unless it is reprocessed earlier) will be kept in water pools next to the reactor (for 10 years) and then moved to an interim storage facility on site (for up to 50 years). The radioactive waste management plan will be developed as a separate document and should be adopted by the Council of Ministers in 2011, following the adoption of the Polish Nuclear Programme.

Direct radiation from radioactive waste does not pose a threat – several meters of soil are enough to confine this radiation underground, and radioactive waste is usually stored several hundred meters below the surface. Therefore, the only risk is that radioactive waste could be washed up to the surface by water. Radioactive substances could be dissolved in water, reach the surface, and be consumed by people, which will cause a radiological threat. To reduce this threat, a number of successive physical barriers are used to contain the possible spread of radioactive substances and absorb radiation. The effectiveness of these barriers depends on their multi-stage design that prevents radioactive substances contained in nuclear waste from getting released, dispersed, sprayed, or washed away with water. Therefore, the degree of exposure of the environment to the negative effects of ionising radiation emitted by nuclear waste is very small, even if we assume a worst-case scenario.

Impact of cooling systems

Two different cooling systems can be used in a nuclear power plant. open-circuit system (without a cooling tower – heat is absorbed by surface waters) and closed-circuit system (with a cooling tower – heat is released directly to the atmosphere). At this stage, designs of cooling systems for nuclear power plants in Poland have not been developed yet. They will be developed for specific locations selected by the investor. An open-circuit cooling system in a nuclear power plant may be used in locations with an access to large reservoirs of cooling water. In practice, this option is possible only for coastal locations and locations in the lower course of large rivers. Seawater is an attractive option given its unlimited resources and lower temperature of water, but the intake and discharge of seawater is a technical problem. On the other hand, water from rivers can be used for cooling purposes in a nuclear power plant, but there are certain limitations to water intake amounts and water heating (after mixing, water temperature must not exceed 26°C). Closed-circuit cooling systems may be fitted with wet cooling towers (with natural draft) and hybrid cooling towers (mechanical draft supported by fans). Different technologies are characterised by different consumption of cooling water (lower for hybrid cooling towers), ranging from about 1 to 2.5 m^3/s (for nuclear power plants with 2 generating units), i.e. from about 25 to 71 million m3/year. Nuclear power plants should be located in areas with sufficient water resources to cover this demand. So far, sufficiency of cooling water resources has not been analysed in detail for the proposed locations. This Report attempts at a preliminary estimate of the sufficiency of water resources. This problem does not apply to coastal locations where seawater will be used for cooling. In the case of river sites in the lower course of the Vistula and the Oder River (including Szczecin Lagoon), open-circuit cooling systems are planned (although the final decision has not been taken yet). In the case of locations at lakes, open–circuit cooling systems cannot be used (due to the existing limitations). Therefore, closed-circuit system (most probably with hybrid cooling towers) must be assumed. For other riverside and inland locations, closed-circuit systems are assumed (usually with natural-draft cooling towers, optionally with hybrid cooling towers). However, in certain cases the available resources of cooling water may not be sufficient to compensate for non-recoverable losses. Demand for raw water of a nuclear power unit with the capacity of 1000 MWe is relatively low (about 530 m^3/d on average).

Operation of cooling systems in a nuclear power plant also involves the emission of heat to water or air, and release of chemicals into water in connection with the water treatment processes. These impacts are summarised in the following table as impacts on surface waters and impacts on the air.

Impacts related to the emissions of pollutants to the air

One of the outcomes of the Programme will include the partial replacement of electricity generation in coal-fired power plants with electricity production in nuclear power plants. As the emissions of pollutants to the air are much lower for nuclear power plants, the Programme will reduce the emissions of pollutants in the atmosphere resulting from electricity generation. This Chapter attempts to estimate the possible reduction of these emissions. Based on data presented in the literature and our estimates, we arrived at a conclusion that implementation of the Programme may potentially reduce emissions of CO2 to the atmosphere by about 18% vs. today's emission levels, emissions of dusts - by about 16%, and emissions of other pollutants from the power sector (SO2 and NO_x) by about 15-17%.

Impact of noise

The level of noise during operation of a nuclear power plant, with no consideration given to background noise and natural topography of the area, will not exceed the acceptable standards within 350 m from noise sources. Therefore, operation of the nuclear power plant will not increase the level of noise in the environment to a considerable extent. Emissions of noise come mainly from operation of cooling towers (fans, pumps, air intake and exhaust vents, and water dripping in wet cooling towers).

Impacts related to the land take

A nuclear power plant is a project that occupies a large area. Therefore, its construction and operation requires that an extensive area of land is excluded – either agricultural land or a meadow ecosystem, depending on the specific location. Deforestation may be also necessary – trees in the area of the planned project must be removed. The actual built–up area depends on the adopted technology – the type of reactor (from 6 to 9 hectares) and installation of cooling towers (4 hectares). The entire nuclear power plant (with 2 power blocks) with the associated infrastructure will occupy about 40 hectares of land. As no detailed location analyses have been performed yet including the determination of land use, these are only estimates based on previous projects involving the construction of similar installations.

As a result of hardening and sealing of the surface area, the amount of water going through to ground waters will be reduced, which may cause lowering of the groundwater level and increased run-off of water from the area to surface waters.

Land take may potentially restrict the access to resources of minerals. The analysis of the available maps of mineral deposits indicates that there are no useful deposits of minerals in the area of the planned projects.

Impact of the infrastructure development

Analyses indicate that the majority of the existing network infrastructure (power transmission lines, transformer stations) may be used for the next 10-20 years. This expected useful life is safe in the case of network facilities such as transformer stations, switches, and 400 kV line components. However, it is too short for 220 kV lines. Implementation of power network investments, including (but not limited to) the connection of nuclear power plants, needs several years to complete the preparation and implementation phase. According to regulations currently in force, this period is about 7 years. Power offtake from a nuclear power plant requires one transformer station and two HV lines. Positive impacts of these investments include the creation of favourable conditions for electricity transmission. Negative impacts in the implementation phase will include an increase in the level of noise, exhaust gases and dusts generated by construction machinery and equipment, as well as the removal of trees and shrubs along the route of the power line and in sections of construction sites. In the operation phase, 400 kV and 110 kV equipment may generate the following environmental impacts: permanent land take for poles and power stations; creation of restricted-use areas; permanent emissions of electromagnetic field; interferences with radio and TV signals; generation of acoustic noise; permanent and significant landscape changes; and permanent risk for birds and bats.

Construction of any power plant, not only a nuclear facility, will require the sufficient amount of cooling water (about 50.2 m^3/s for the nuclear power unit). Therefore, the appropriate infrastructure must be provided for the intake and discharge of heated water. In addition, it will require an extension or modernisation of the local road network and elements of the railway network, as well as building of piers/wharfs for the loading and unloading of large or overloaded cargo including construction equipment and components (in the case of power plants located at large rivers or the sea). Development of the infrastructure will require the use of certain environmental resources (especially water and energy), just as for any other large industrial plant. Passenger and technical transport vehicles will generate additional emissions of exhaust gases to the environment. However, these amounts will not be considerable. We should note that passenger traffic will be more intensive than traffic of technical vehicles, given the low demand for raw materials but high demand for workforce (high number of employees on site). Operation of the infrastructure will also produce waste.

Impacts on the landscape

Impact of the nuclear power plant on landscape is closely related to the location of the project and type of land use in the neighbouring areas. Therefore, it depends on the scale of the investment, cubage of buildings and facilities, and the associated infrastructure, as well as the urban layout and components of the natural environment in the area. Therefore, the expected impacts cannot be precisely defined at this stage. Still, we may analyse impacts recorded for the adopted reference projects.

It seems beyond any doubt that all large investments in the power sector change the existing spatial arrangement. These changes include single point, surface, and linear objects (such as roads or transmission lines). Their vertical range (and thus visibility from a distance) is also diversified. Given that a qualitative evaluation of this interference is difficult, we could use quantitative data for a project with a comparable or generally high electricity production capacity (e.g. in terms of the area occupied by the project or the area where raw materials are extracted). The following examples illustrate different methods of presentation of various projects and how it influences the way we perceive these projects. Supporters and opponents of various types of investments often use quite different images – photographs of landscapes.

LIGNITE-FIRED POWER PLANTS

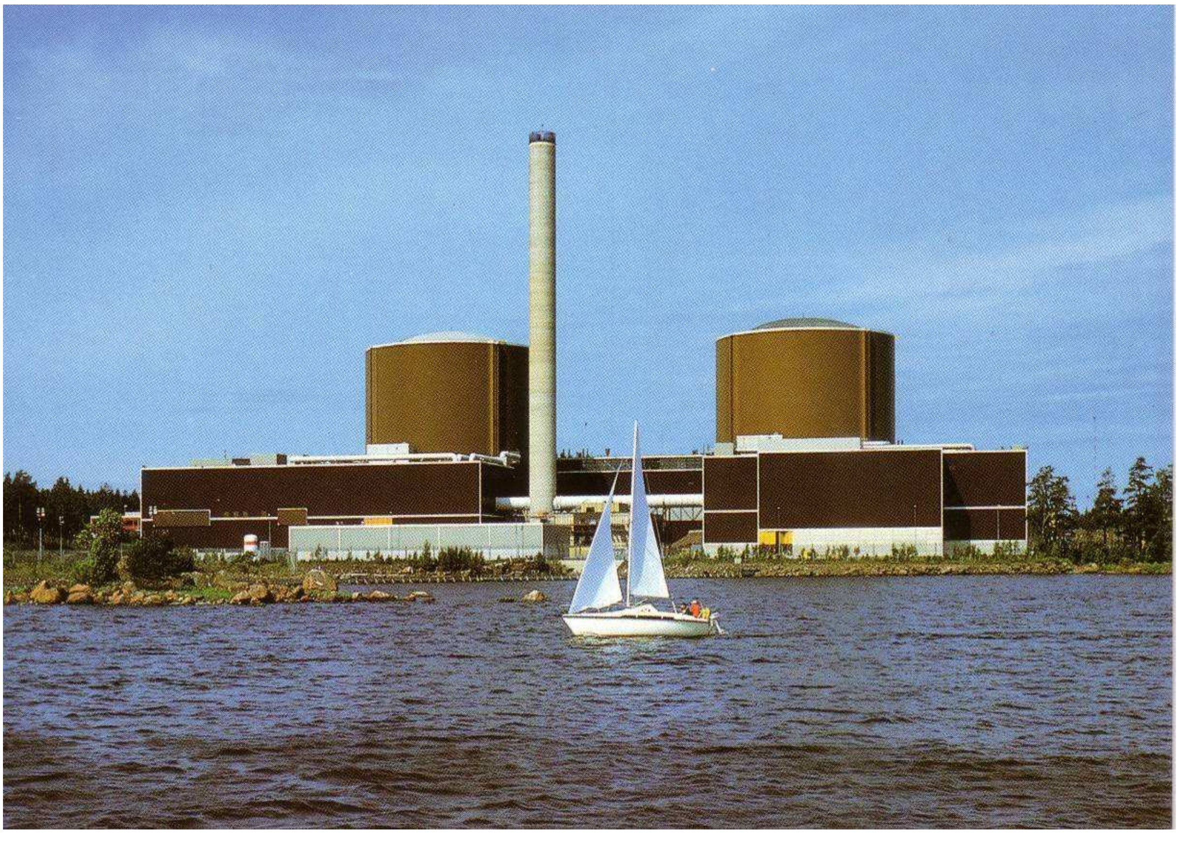
WIND TURBINES

NUCLEAR POWER PLANTS

Landscapes in the area of various types of power plants – examples of one-sided presentation

To some extent, operation of a nuclear power plant depends on good communication – including transport by road or rail and power lines. The first two problems seem marginal, given that fuel deliveries and removal of spent fuel are not too frequent, and the number of people who come to work at the power plant is not too high. However, high-capacity transmission lines and the associated infrastructure will definitely change the original spatial arrangement. Still, this effect is observed for all large electricity–generating facilities, irrespective of the technology, and in all places where transmission lines are installed – even if there is no power plant in the area. The following photographs illustrate examples of the siting of large facilities (nuclear power plants) in the surrounding landscape, in accordance with the principle of keeping the negative impacts on the landscape at a minimum.

Nuclear power plant in Neckarwestheim (Germany)



Nuclear power plant in Loviisa (Finland)

Social and economic impacts

The impact of a nuclear power plant must be also analysed in terms of its operation as a very important production facility. As such, the project will be of high importance for the economy of the specific municipality and of the neighbouring municipalities. This impact will include:

- higher value of land in the area
- increased income of the municipality
- improved infrastructure

- lower unemployment rate
- economic revival in the region
- higher energy safety in the region

Natural threats to the operation of a nuclear power plant

Natural threats are understood as the impact of nature's forces that poses a threat to human life and health or to human-made infrastructure. As a rule, these are extreme or abnormal phenomena. They include extreme weather conditions (storms, tornados, droughts, etc.), hydrological phenomena (storms, floods, low water, etc.), seismic events (earthquakes, rock bursts), mass movements (avalanches, landslides, mud and debris flows), as well as events in the biotic world (such as locust swarms etc.). They are rather unpredictable, occur suddenly, and have serious consequences for the economy.

The Report analyses all threats defined in the regulation of the Council of Ministers on the requirements for nuclear power projects. These threats apply both to nature's forces and to engineering solutions adopted for the potential investments. At the stage of development of the SEA Report and with no concrete data on the adopted engineering solutions and the selected location, we are not able to refer directly to all these requirements. Still, the key factors connected with natural threats to nuclear power faculties and the associated infrastructure are described.

As far as earthquakes are concerned, no strong, large or extreme earthquakes have been recorded in Poland for the past 1000 years – only moderate earthquakes that can affect only buildings in a bad technical condition, and only to a limited extent. Maintaining the construction standards prescribed by the International Atomic Energy Agency (IAEA), selection of proper building materials, and technical control and proper maintenance of nuclear power facilities under operation should guarantee absolute safety of nuclear power plants in Poland as regards their resistance to seismic shock.

Geotechnical and hydrogeological threats should be eliminated by the proper analysis of ground conditions during preparatory works for the project and by using top-quality building materials and techniques Therefore, detailed analyses of the geology of sub-surface layers and the system of groundwaters are of key importance. Accurate determination of the existing hydrogeological and geological conditions and application of the proper building technologies will guarantee stability of the nuclear power plant when its operation starts.

Weather conditions that may pose a threat to safety in a nuclear power plant include mainly snowfalls and rainfalls (and also hail) – their intensity, frequency, and time; wind – its speed and gustiness; atmospheric discharges; extreme temperatures; and other phenomena, such as tornados. Adverse weather conditions will affect mainly the safety of the associated infrastructure of a nuclear power plant, including electricity transmission lines. They can be expected especially in winter months. In the winter of 2009–2010, HV power lines would break down under the weight of ice. However, the problem concerned mainly old lines that had not been properly maintained. It may be expected that a properly designed, constructed, and managed nuclear power plant will be resistant to extreme weather conditions. The same applies to the related associated services, including proper organisation of transport of fuel and spent fuel.

Hydrological risks are of key importance for all potential locations of nuclear power plants at the bottom of river valleys. The specificity of the technological process that requires water for cooling eliminates the possibility to move a nuclear power plant at a large distance from water intake points.

High water is one of hydrological risks that require special attention. The increase in water level due to oversupply of water or a blockage along the river course is generally considered the highest risk in Central Europe. In Poland, floods – defined as high water that affects people's lives – occur in various rivers each year and practically during all seasons. The most serious floods affecting a large part of major river basins occur in the warmer seasons of the year. Floods are also a problem in the melting season – in spring and mid-winter. There is one another category – floods that are caused by the build-up of ice or slush-ice, affecting mainly rivers in lowlands (such as the annual ice build-up in the Włocławek part of the Vistula). With the currently available building technologies and engineering solutions, it would be possible to protect a nuclear power facility against the negative effects of even the highest water levels. A well-designed nuclear power plant and the associated infrastructure should not be affected by floods. On the other hand, low water (i.e. lowering of the surface and ground water levels) may also become a problem. A nuclear power plant must have access to sufficient water resources. If this water comes from surface water courses, its level must not drop below the minimum flow limit that is required by organisms living in that water course.

Non-radiological impacts at the nuclear decommissioning stage

Demolition works will produce higher emissions of dusts into the atmosphere and higher noise levels. These emissions may be considered a nuisance by inhabitants of the surrounding area. However, they will be only temporary and should not be particularly problematic, given that nuclear power plants are located away from residential areas. Decommissioning of a nuclear power plant will produce large amounts of waste that should be reused or recovered to the highest degree possible or neutralised.

All buildings should be completely demolished, and the area must be cleaned and recultivated. If these works are successfully completed, the impact of the decommissioning stage is considered positive – it removes 'foreign' elements from the landscape. Removal of the large hardened surface will also have a positive impact on soils and waters in the area, leading to the restoration of biologically active surfaces and the natural circulation of water by allowing its infiltration into the ground.

Impact on biodiversity, including biological resources protected under the Natura 2000 network

Construction of a nuclear power plant involves certain environmental impacts. They may include the impact of such a large project on the flora and fauna, or more broadly speaking – on the entire biodiversity and Natura 2000 sites. At the current stage of works, as the location for the project has not been selected yet, it is difficult to predict the specific impacts in this area. All potential locations have different sensitivity and there are only few common impacts that can be assumed for all proposed location to a similar extent. Each location is different in terms of the protection of plants, animals, biodiversity, or Natura 2000 sites.

In addition, every stage of the project has different negative impacts – in terms of their type or severity. Land take has a different importance on the (broadly defined) protection of nature at the construction stage, when modification of the existing environment is the most severe in comparison with the operation stage, when the environment has already been modified and is subject to permanent and repeatable impacts caused by the operating facility. Impact of the nuclear decommissioning stage is again different, as it involves the use of heavy construction machinery.

Therefore, each location has a different degree of sensitivity to various impacts in all phases of the project, given its geography and natural resources. With the large number of these potential impacts, combined with the gaps in knowledge due to the lack of specific studies dedicated to individual locations, we can only list a number of potential impacts but we cannot assign them to any specific location.

We should also note that different actions taken in the course of the project may result in similar environmental impacts; for instance, increased death rate among animals may be caused both by overhead power lines and by vehicle traffic.

In conclusion, if the Programme is given a green light, we can assume that any of the identified negative impacts can be observed in any location. The specific impacts assigned to the selected locations will be analysed at the EIA stage.

1.9 Identification and description of the expected environmental impacts of the Programme

Summary of the identified significant impacts

Significant impacts on biotic elements of the natural environment identified and described in the SEA Report resulting from the implementation of the Polish Nuclear Programme are summarised in the following table. The authors believe that this form of presentation of data will be easier for the reader. Description of the expected impacts on the individual components of the natural environment is broken down into construction, operation, and decommissioning phases for a potential nuclear power plant.

PHASE	DESCRIPTION OF EXPECTED IMPACTS
	Impact on humans
CONSTRUCTION	**Noise will not reach significant levels**, because nuclear power plants will not be located in the vicinity of any residential areas. The transport route leading to the construction site should minimise any nuisance factors for the local population. **Increased dust level** is always associated with the construction of large projects, but it can be effectively reduced by introducing preventive measures. **New jobs** will be created.
OPERATION	**Emissions of radiation** during normal operation of a nuclear plant are within the adopted standards. Radiation doses are much lower than the current average annual radiation dose caused by natural radiation (for instance from rocks), medical sources, or emissions from other industrial sources. Additional radiation dose from a nuclear power plant is also much lower than the difference between doses in individual Polish towns and cities, which means that an inhabitant of Wrocław who decides to move to a city like Kraków will be exposed to a much higher dose of radiation than they would be exposed to in Wrocław if a nuclear power plant was built right in front of their house. In the particular example discussed in the Report, emissions of radiation had no negative effects on humans within 20 years of the plant's operation.
	Effects of small doses of radiation that may be emitted during normal operation of a nuclear power plant were the subject of long-term studies involving the population and selected groups of employees or patients. It was found that small doses of radiation have no negative impact on people's health. Quite on the contrary, most studies indicate that the impact of small doses of radiation is even positive for living organisms, including humans, as they have an anti-cancer effect.

PHASE		DESCRIPTION OF EXPECTED IMPACTS
		Noise is emitted by plant and machinery operated on site. The nuisance level depends mainly on the actual location of a nuclear power plant. Noise levels may be higher for plants with cooling towers. Noise should not be a major nuisance factor for humans, as nobody will live in the restricted-use area (about 800 m around the nuclear power plant).
		Supply of electricity and improvement of the natural environment Introduction of nuclear power in Poland will improve the country's energy security and ensure reliable supplies of electricity to end users at relatively low cost. Generation of electricity in nuclear power plants will produce less air pollution. Therefore, condition of the natural environment will be improved by reducing the current level of emissions from the power sector.
	Accidents	In the event of a nuclear reactor breakdown, the key threat is connected with radioactive substances released to the environment through air (mainly) or water. These substances may be either inhaled or ingested by humans. Therefore, all reactors have an entire system of safeguards and protections – including devices and solutions that prevent the potential release of significant quantities of radioactive substances to the environment. Still, we must note that a potential serious accident that would result in significant releases of radioactive substances to the environment, primarily to air and (in smaller amounts and with lower likelihood) to water, could pose a serious threat to people's health. However, considering the adopted safeguards and state-of-the-art technologies to be used in the first nuclear power units in Poland, the risk of such a serious breakdown is virtually eliminated. Radiological protection procedures have been defined and will be followed in any emergency situation. These intervention measures will minimise any potential negative health effects. The design of new-generation reactors meets the safety requirements defined in draft Polish legislation and in generally accepted European standards. Design-basis accidents will require no intervention outside of the restricted-use area (about 800 m around the plant). Serious accidents may require measures such as administration of stable iodine, but will not affects people's lives in any other way, and their probability is less than once in a million years of the reactor's operation.
DECOMMISSIONING		**Emissions of radiation** during and after nuclear decommissioning will pose no threat to humans. Employees working on nuclear decommissioning will be exposed to doses of radiation that are comparable to normal radiation doses emitted during normal operation and maintenance of a nuclear power plant, and these doses will not cause any harm to their health – as confirmed in a study involving 500,000 people working in the nuclear power sector. **Noise** will be an insignificant nuisance factor, as the nuclear power plant will not be adjacent to any residential area. Transport will be also a source of noise. However, the selected transport route should minimise any nuisance factors for the local population. **New jobs** will be created.
Impact on surface waters		
CONSTRUCTION		There will be no significant negative impact on surface waters in the construction phase. We may only expect local changes in water circulation caused by the fact that ground waters will be pumped out of excavations and trenches and released to surface waters.

PHASE		DESCRIPTION OF EXPECTED IMPACTS
OPERATION		**Emissions of heat** to surface waters will increase their temperature. The increase in temperature of surface waters is limited by law. The temperature of heated water released to surface water bodies must not exceed 35°C for rivers and seas, and 26°C for lakes and their tributaries. Excessive increase in the temperature of surface waters may facilitate the growth of aquatic organisms and excessive fertilisation (eutrophication) of surface waters. The temperature of water has a direct impact on all living organisms and their physiological processes, and an indirect impact on the amount of oxygen dissolved in water. If water is heated up, it affects the solubility of oxygen and facilitates decomposition of organic matter, which leads to faster consumption of oxygen. The actual increase in the temperature of a water body that will accept the heat released by the nuclear power plant can only be calculated for the specific location. A detailed analysis will be conducted after the project location has been determined, and the increase in temperature will be precisely defined in °C on this basis. The water reservoir used for cooling purposes will be analysed in detail during the operation phase to determine the scope and type of impacts caused by the release of heat.
		Chemical pollutants are released to water from products used to prevent depositions on the surface of elements of the cooling water system, disinfectants, and products of corrosion in heat exchangers and piping. In *nuclear power plants on river sites*, additional water used in the cooling system or cooling water itself must be treated. Various water treatment methods will produce deposits that contain some heavy metals. Deposits are collected in special sedimentation tanks, condensed, dried, and removed to landfill dumps. Deposition of this type of waste has no negative impacts on the environment. As calcium and magnesium are removed in the form of deposits, the content of dissolved substances is lower in water released to surface water bodies compared to water that is taken in. In nuclear power plants on coastal sites chlorine must be used to maintain the required purity of water used in water circulation systems. Chlorine reacts with organic compounds and can form harmful chemicals. If concentrations of various chemicals in water released to surface water bodies do not exceed the adopted standards by 1%, their impact may be considered negligible. Oxidising compounds are the only substances that exceed the adopted standards. However, they are very short-lived and they decompose quickly, so the standards will be exceeded only in the closest vicinity of the water discharge area.
	Accidents	A potential release of radioactive substances to surface waters may occur only as a result of a very serious accident. New-generation reactors include additional systems and structures that protect the integrity of the safety containment and the foundation slab. As a result, the risk of an accidental release of radioactive substances is reduced practically to zero. However, in the event of an accidental release of radioactive substances to the atmosphere, radioactive particles will slowly deposit on the surface of the ground, or will be washed away quickly by rain or snow and will finally get to surface water bodies. Depending on the existing weather conditions, potential pollution of surface waters is therefore possible.
DECOMMISSIONING		No significant negative impact on surface waters is expected in the nuclear decommissioning phase.
Impact on ground waters		

PHASE		DESCRIPTION OF EXPECTED IMPACTS
CONSTRUCTION		**Pollution of groundwater** in the construction phase is possible in areas where ground waters are not isolated from the surface and are therefore sensitive and highly sensitive to pollution. Areas where ground waters are separated from the surface with an impermeable layer of clay offer the best protection of groundwater from potential pollution. **Changes in hydrographical conditions** may be caused by earthworks, especially where ground waters are located close to the surface. Deep excavations need intensive drainage works, which may drain the adjacent areas. However, excavations required to build nuclear power plants are not too deep – the maximum depth will not exceed 14.00 m. A large hardened area, including the nuclear power plant and the associated infrastructure, may change the level of shallow groundwater and cause the local drainage of the surface.
OPERATION		**Potential pollution of groundwater** is rather unlikely. All structural elements, systems, and equipment in a nuclear power plant will meet very stringent quality control standards, environmental protection norms, supervision standards, and Best Available Technology requirements, which will minimise the risk of potential accidental release of harmful substances to the ground. Storage containers, storage areas for chemical substances, fuel unloading areas and areas of other works that could cause environmental pollution will be located on hardened surfaces or confined with leak proof barriers that will contain any possible releases of harmful substances. Therefore, operation of the nuclear power plant will have no impact on the quality of the ground and groundwater – unless a serious accident occurs. To control the quality of groundwater in the area of the nuclear power plant, groundwater will be sampled to detect any potential pollution.
		Changes in groundwater levels may be caused by the hardening of a large area that will reduce the infiltration of water into the ground. The level of groundwater will be controlled, and the impact of the project on the local changes of groundwater flows in the area of buildings will be determined.
	Accidents	**Release of radioactive substances** to groundwater may occur only as a result of a very serious accident. New-generation reactors include additional systems and structures that protect the integrity of the safety containment and the foundation slab. Polish regulations provide that reactors cannot be built without these systems that ensure proper protection of the safety containment. As a result, the risk of an accidental release of radioactive substances is reduced practically to zero. **Release of other substances** may be caused by uncontrolled leakages. Therefore, provision of emergency water collection tanks and development of emergency procedures is a key element in the design and construction phase. In the event of any accidental release of pollutants, an emergency procedure will be launched to detect and neutralise source of the leakage and the contaminated area in order to prevent the pollution of groundwater.
DECOMMISSIONING		Complete removal of buildings and the associated infrastructure, including all hardened surfaces, will have a positive impact on water resources by increasing the infiltration area.
Impact on the air		

PHASE		DESCRIPTION OF EXPECTED IMPACTS
CONSTRUCTION		**Emissions of pollutants during the production of materials** required to build the nuclear power plant are relatively low, given that the demand for materials is relatively limited (per one unit of electricity production). Therefore, emissions of gases and dusts into the air during the construction of the nuclear power plant and production of the associated equipment are much lower than in the case of other electricity production facilities. Long-term works under the EU's EXTERNE programme have confirmed that nuclear power plants are the most environmentally-friendly and human-friendly of all sources of energy. **The level of dust** will increase due to construction works. However, this level may be reduced, for instance by sprinkling. The amount of materials required to build the nuclear power plant is relatively small (per one unit of electricity production), and therefore the level of dust generated in the construction phase is also low. **Emissions of exhaust gases from vehicles and machines** are related to the increased traffic of heavy machinery. This impact will depend on the location of the construction site and the selected access route.
OPERATION		**Potential reduction of air pollution** resulting from the introduction of nuclear power in Poland was evaluated based on the analysis of emission volumes from various energy sources for the entire electricity production cycle (from the extraction of raw materials up to the deposition of waste). This analysis indicates that emissions of gases and dusts in a nuclear power plant are the lowest in comparison with coal-fired power plants. It was determined by calculation that the potential reduction of air pollution is considerable – from 15% to 17% for different types of pollutants.
		Emissions from cooling towers are related to the release of water contaminated with water treatment products or microorganisms (if the water treatment system is ineffective) to the atmosphere. These problems should be eliminated by an effective water treatment system, and their impact will be only marginal.
		Emissions of exhaust gases are generated from transport vehicles and emergency power generating units. Their impact will be only temporary and will depend on the specific location and the transport infrastructure on site. Emissions related to the transport of fuel and waste (in small amounts) will be limited compared to the transport of employees.
	Accidents	In the event of a serious accident, a potential release of radioactive substances to the atmosphere will be the most likely source of radioactive pollution. Impact of the radioactive cloud and its spread in the air will depend on the weather.
DECOMMISSIONING		The nuclear decommissioning phase will involve an increase in heavy machinery traffic and the related increase in the emissions of exhaust gases to the air. This impact will depend on the location of the construction site and the selected access route.
Impact on the climate		

PHASE	DESCRIPTION OF EXPECTED IMPACTS
CONSTRUCTION	Emissions of greenhouse gases (mainly CO2) are related to the operation of construction equipment and transport of building materials and the workforce to the construction site. These emissions will not create any major nuisance for the local environment. They do not represent significant values in the global balance, because they will be limited to the construction and decommissioning phases (short-term impact).
OPERATION	**Potential reduction of GHG emissions** results from the fact that production of electricity in nuclear power plants generates no CO2 emissions, and the introduction of nuclear power plants to the electricity production sector will reduce CO2 emissions, which may have a positive impact on the climate. Very low emissions of CO2 will be generated in the construction and decommissioning phase, as well as during the fuel cycle.
	Emissions of heat to the atmosphere results from the generation of heat as a side-product of electricity production. Heat may be transferred through a water environment, and it is released to the atmosphere gradually (evaporation, radiation from water surface, and absorption in air). Given the large temperature differences, these processes may produce fog in the area where heated water is discharged. The area covered by fog will be limited. Heat may be also released to the air directly from cooling towers. Cooling towers will release humid and heated air. This air cools down and produces a cloud of vapour. The cooler and more humid the surrounding air, the longer the cloud will remain in the air. This process, as well as the process of deposition of the cloud on the surface of the ground, will depend on the weather and design of the cooling tower. Fogging may also be more intensive in the surrounding areas.
	Accidents: No major impacts.
DECOMMISSIONING	Emissions of greenhouse gases (mainly CO2) are related to the operation of construction equipment and transport of building materials and the workforce to/from the site. These emissions will not create any major nuisance for the local environment. They do not represent significant values in the global balance, because they will be limited to the construction and decommissioning phases (short-term impact).
Impact on the Earth's surface	
CONSTRUCTION	Impact on the Earth's surface will depend on the scale and phase of the project. The key impacts will include exclusion of the biologically active surface and changes in the ground structure (compaction, removal of a humus layer, etc.). The potential impacts also include the pollution of soil with petroleum products that mat be released into the ground due to leakage or breakdowns of mechanical vehicles.

PHASE	DESCRIPTION OF EXPECTED IMPACTS
OPERATION	**Land take** The area occupied by the nuclear power plant and the associated infrastructure depends on the adopted technologies and may reach 40 hectares. Hardening of this surface will reduce the biologically active area and the infiltration of water.
	Production of solid waste: - radioactive waste – 30 tonnes/year - chemical and inert waste – 294 tonnes/year - hazardous (non-radioactive) waste – 63 tonnes/year
	Accidents: In the event of an accidental release of radioactive substances to the atmosphere, radioactive particles will slowly deposit on the surface of the ground as the radioactive cloud spreads out, or will be washed away quickly by rain or snow, depending on the weather. As a result, contamination of soil is possible.
DECOMMISSIONING	Complete removal of all facilities and infrastructure of the nuclear power plant and proper recultivation of the area that restores the former condition of land will have a positive impact on the Earth's surface.
Impact on the landscape	
CONSTRUCTION	Impacts on the landscape will depend on the specific location and the type of land use in the neighbouring areas. In the construction phase, it is also of key importance to select the most optimum route for the transport of building materials. Impacts on the landscape will result not only from the construction of the nuclear power plant, but also the associated infrastructure, including access roads, overground power lines, and water intake and discharge piping. The construction phase will probably have more impacts on the landscape than the operation phase (high cranes).
OPERATION	**Nuclear power plant buildings** will have an impact on the landscape that will depend on the specific location and the type of land use in the neighbouring areas. Cooling towers will change the landscape even more. The impact of a nuclear power plant without cooling towers in much lower.
	Associated infrastructure Power lines connected to the nuclear power plant will be a key element of the associated infrastructure. They will cross both natural systems and man-made systems. The scale and type of impacts caused by power lines will depend mainly on their linear layout and technical parameters (i.e. height of utility poles, type of structures - tubular poles or lattice towers) that will clearly change the landscape.

PHASE		DESCRIPTION OF EXPECTED IMPACTS
	Accidents	A potential accident will have no impact on the landscape. However, protection of the area after a breakdown may affect the environment.
DECOMMISSIONING		It is expected that nuclear decommissioning, involving the complete dismantling of all facilities and structures and restoration of the area to the condition as close to the original state as possible, will have a positive impact on the landscape.
Impact on natural resources		
CONSTRUCTION		Construction of a nuclear power plant will involve the consumption of large amounts of water and mineral resources used to build power generating units and the associated infrastructure. At the same time, it will generate large amounts of waste. (including inert, construction, and municipal solid waste and sewage). There are no useful deposits of minerals in the area of the planned investment, so access to mineral deposits will not be restricted during the construction phase.
OPERATION		**Securing the supply of nuclear fuel for the project** – in the short-term perspective (about 20 years) nuclear fuel will be purchased from foreign suppliers of technologies or other producers (if this option proves more economically viable). Production of nuclear fuel in Poland is not a feasible alternative given the relatively limited scale of the nuclear power projects and current prices of uranium ore. In addition, the analysis of deposits available in Poland indicates that they are rather limited and economically non-viable, and the demand will rather be covered from external sources. However, as the nuclear power sector develops and market prices of uranium increase, extraction of the country's uranium ore deposits may become viable in the future, and the nuclear fuel processing infrastructure may develop in Poland.
		Reduced consumption of raw materials We can expect that the development of nuclear power will result in a significant reduction in the demand for fossil fuels – from 20% to 25% depending on the adopted option.
	Accidents	No major impacts.
DECOMMISSIONING		No direct impacts of the nuclear decommissioning phase on natural resources were identified.

PHASE	DESCRIPTION OF EXPECTED IMPACTS	
Impact on historical buildings/cultural resources		
CONSTRUCTION	A nuclear power project will have the same impact on the country's historical heritage as any other large building covering a similar area. The most serious problem is related to the destruction of archaeological sites, but it is rather unlikely – any works performed in areas that include documented archaeological sites will be supervised and approved by the Regional Building Conservation Officer. In addition, construction works covering such a large area may actually lead to the discovery of new undocumented sites of cultural significance and their subsequent exploration.	
OPERATION	At this stage, the impact on historical monuments is difficult to predict, and the actual location for the project has not been selected yet. However, given the specific type of the project, it is rather unlikely that it will have any impact whatsoever on the movable cultural assets, and the potential locations do not overlap with the UNESCO World Heritage Sites. We should therefore focus on the potential impact on immovable cultural assets and archaeological sites. This impact will be determined only in the EIA Report prepared for the specific location where the nuclear power plant will be built.	
	No negative impact on historical buildings and other cultural resources is expected in the operation phase. On the contrary, we may venture to say that the project will reduce the pollution that may have a negative impact on the structure of historical buildings and other cultural assets. As the nuclear power plant will provide a source of electricity, new coal-fired or gas-fired plants will not be built in the area and their current number may even be reduced, which will also reduce emissions of harmful substances to the air. When combined with water, substances emitted by coal-fired power plants cause acid rains that dissolve and change the surface of stone buildings and structures. This risk applies in particular to structures made of limestone and marble – they are composed mainly of calcite that is dissolved in acids relatively quickly.	
	Accidents	No major impacts.
DECOMMISSIONING	No significant negative impacts on cultural assets are expected in nuclear decommissioning phase. Impacts will be comparable to those caused by the dismantling of any other facilities covering a similar area. In the areas adjacent to places of historical and cultural significance, the site may be brought to the state that corresponds to the land use in the surrounding areas.	
Impact on material assets		
CONSTRUCTION	Construction of a nuclear power plants will require significant investments. Therefore, in a short-term perspective it will consume material assets. Only after the construction phase is completed can we expect a positive impact in the context of the economic balance.	

PHASE		DESCRIPTION OF EXPECTED IMPACTS
OPERATION		The analysis of examples of nuclear power projects indicates that operation of a nuclear power plant may have a positive impact on material assets: - increased value of land in the area of the investment (the initial drop is only possible at the beginning of the construction/operation phase) - increased income of the municipality - improved infrastructure - lower unemployment rate - economic revival in the region
	Accidents	Any potential accident will cause significant material losses suffered by the investor and the adjacent areas – which must be partially compensated in accordance with the current provisions regarding the liability for nuclear accidents.
DECOMMISSIONING		Nuclear decommissioning will be financed with funds deposited in a special bank account during the operation of the nuclear power plant, in accordance with draft amendment to the Atomic Energy Act. The impact on material assets will depend on how the area of the former nuclear power plant will be managed.
Impact on biodiversity, including biological resources protected under Natura 2000 network		
CONSTRUCTION		Like any other large investment, construction of a nuclear power plant will have an impact on the natural environment. Selection of an optimum location is the key. If the selected location is not recommended for reasons related to environmental protection, the integrity and objectives of Natura 2000 sites may be affected, functions of ecological corridors undermined, habitats fragmented, and valuable species endangered (both at the country's and international level). If a less sensitive location is chosen, significant negative impacts are not expected.
OPERATION		In the operation phase, the extended overhead traction network will have a significant impact. In some locations, it may cause the increased death rate among large flocks of migrating birds. Other significant impacts will include discharges of heated water to rivers or other water bodies, which may lead to changes in ecosystems and affect biodiversity (a two-way impact involving both negative and positive aspects).
	Accidents	As the risk of a radioactive leakage in nuclear power plants that are allowed in Poland is negligibly small, the release of a radioactive cloud is the key threat. Depending on the weather conditions, it may lead to contamination that will affect living organisms to a greater or lesser extent.
DECOMMISSIONING		The complete decommissioning of a nuclear power facility and restoration of the environment to the state as close to natural as possible will ultimately have a positive impact on the natural environment. However, demolition work itself may have a negative impact on Natura 2000 sites (in sensitive locations), as it will generate vibrations, noise, possible contamination of surface and ground waters, and may also temporarily affect functions of the ecological corridor.

Description of impacts

The identified impacts were presented based on their source and origin (direct and indirect, secondary), duration (short-, medium, and long-term), and frequency (permanent and temporary), as well as the probability of their occurrence. Impacts were also classified in terms of their direction (negative and positive) and scale (moderate and significant).

In the construction phase, many negative impacts were identified (affecting all elements of the natural environment except the climate), the majority of which are temporary and short-term. Positive impacts on humans were also listed (creation of new jobs).

In the operation phase, the identified significant negative impacts (on humans, water, and air) will occur only in emergency situations, but their likelihood is very low (the impact is nearly impossible and assumed only in a worst-case scenario). Other negative impacts will be moderate. We can also expect significant positive impacts on humans (related to the reliability of electricity supplies and the overall improvement of the natural environment), on the air (reduced emissions of gases and dusts to the atmosphere), on the climate (reduced emissions of carbon dioxide), on natural resources (reduced consumption of fossil fuels), and on material goods (improved energy security in the country).

In the decommissioning phase, the identified negative impacts (on humans, water, Earth’s surface, natural resources, and material goods) are less frequent than in the construction phase, and are mostly temporary and short-term. At the same time, positive impacts on humans, the air, the Earth’s surface, the landscape, and natural resources were identified.

Possible environmental impacts of the Programme in the neighbouring countries

At this stage of a strategic document (the Polish Nuclear Programme), the assessment of environmental impacts in neighbouring countries can be only preliminary. To evaluate these impacts, an analysis was conducted to decide which countries could be affected by the potential impact in the operational phase of the planned nuclear plant in Poland.

Considering the small likelihood that the first nuclear power plants in Poland will be built in one of the locations defined as “other” in the Programme, we can conclude than none of the neighbouring countries will be exposed to any impacts (direct or indirect). However, if we assume that any “other” location is selected, Germany will be exposed to direct impacts from the Polish nuclear power plant. Germany, Belarus and Russia are the countries whose societies may be potentially interested in the participation in social consultations (given the distance from the potential sites).

In the context of the analysis of transboundary impacts it should be also pointed out that Poland is not a pioneer in the nuclear power sector. Apart from Lithuania and Belarus, all other neighbouring countries operate nuclear power plants in their territory.

Analysis of potential social conflicts

The draft Polish Nuclear Programme (p. 95) provides that “social support for nuclear power is one of the most important pre-conditions for the Polish Nuclear Programme” and that “steady and conscious support (or at least acceptance) of the majority of the society is a condition precedent to the introduction of nuclear power that will prevent the Programme being used as a subject of political debates”. The draft gives a figure for the support declared by the Polish society for the introduction of nuclear power at 40-50%. At the same time, it was emphasised that this support is unstable and to a large extent it is not based on the society's knowledge of nuclear power, which is an outcome of 20 years of no education whatsoever in this area, among other.

When actions towards the development of nuclear power in Poland were resumed, social conflicts became a fact and the public opinion was clearly divided from day one. It is all happening despite the fact that for quite some time articles in the press have been forecasting an ever-increasing demand for electricity and potential problems with electricity production in the future[1].. Some environmental organisations criticise the potential locations and the very purpose and safety of nuclear power projects. At the same time, the fierce protests of environmentalists reported in the media, combined with actions taken to disrupt the implementation of major infrastructural projects important for the country or local communities (even those that are reasonable and based on sound argumentation), trigger protests from other groups in the society. In the worst-case scenario, the significance of environmental initiatives may be undermined by the excessive and stubborn focus on single elements of the natural environment of relatively minor importance for the entire ecosystem.

Social conflicts are an inherent part of any large project. In holds true in particular in the case of investments in the energy sector. Not a long time ago, environmentalists voiced their protests against projects such as construction of the Niedzica dam on the Dunajec River, the man–made Czorsztyn Lake, or the Niedzica – Sromowce Wyżne Hydroelectric Power Plants. In more recent years, wind power projects are the source of serious conflicts. Wind farms projects with wind turbines were rejected by the inhabitants and local authorities in many regions of Poland. Villages in the Kłodzko Valley or the Kaczawskie Foothills are just one example. In addition to the significant impact on the landscape and risks for birds and bats, opponents of wind power projects claim that wind turbines may have an impact on people's health and well-being. Projects of new open-pit mines and brown-coal mining projects for the purposes of electricity generation are as controversial. The plans of relocation of villages north of Legnica encountered a backlash from the protesting local communities. An initiative called 'STOP the PIT' was set up. Inhabitants of these areas reject the proposed compensatory payments and refuse to relocate.

Public opinion on nuclear power in Poland and other electricity production methods and technologies is summarised in the report of CBOS (Public Opinion Reserach Centre) published in September 2009 titled "Public Opinion on Nuclear Power. Quantitative Research Report" ("Opinie o energetyce jądrowej. Raport z badań ilościowych"). The respondents were requested to evaluate the efficiency of the following sources of energy: bituminous coal, lignite coal, crude oil, natural gas, nuclear energy, biofuels, hydropower, solar energy, wind power, and geothermal energy.

Findings presented in the CBOS Report are as follows:

- public support for the nuclear power plant project in Poland is increasing, but its supporters include usually well-educated people;
- lack of knowledge of nuclear power gives rise to fear and concerns that are expressed in the form of protests against the construction of a nuclear power plant or location of a radioactive waste depository;
- arguments of opponents always focus on irrational fears and general concerns;
- information and argumentation must be targeted mainly at social groups with a lower education level and inhabitants of rural areas, as well as young people (aged 15–17 lat) whose knowledge of nuclear power is simply a disaster;
- a radioactive waste dopository raises more concerns than a nuclear power plant;

- any location for a radioactive waste depository will be accepted only on condition that it is properly protected with safety measures, but at the same time we may expect that the effectiveness of these safety measures will be questioned;

- there is a wide social support for compensatory payments for inhabitants of areas close to a nuclear power plant – they should include a number of elements, with special focus on health care and reduced electricity charges;

- the self–assessment of the respondents' knowledge of nuclear power is very low – Poles are well aware of the fact that their knowledge is poor; at the same time, data clearly indicates that the level of knowledge corresponds to the level of acceptance. The knowledge of nuclear power comes mainly from the media: the press, TV, and radio. Less than 1 in 5 respondents declares that he or she gained this information from school, university, or work.

Findings presented in the CBOS Report are very interesting. Special attention should be given to the society's low level of knowledge of nuclear power, as well as the sources of this information – the public media rather than school curricula or specialist publications. Still, public approval for nuclear power in the period 2008–2009 increased by nearly 70%, and nuclear energy ranked second (after renewable sources) among all suggested options for the development of the energy sector.

Information on the feedback to nuclear power in other countries, especially in countries where nuclear power plants are in operation, is presented in the Study no. OT-575 "Reaction of the local European communities to the proposed location of a nuclear power plant in their close vicinity" prepared by the Analyses and Documentation Office, Analyses and Topical Papers Unit of the Chancellery of the Polish Senate in November 2009. This study is an attempt to answer the question whether it is possible and acceptable to locate nuclear power plants in a region attractive for tourists and what the consequences for the local community are. Regions that are attractive for tourists often overlap with regions of high natural or scenic value, and therefore this study has a deeper meaning. The study concludes that no examples were found that location of a nuclear power plant will affect tourism in a given village/town. It also underlines the positive impact of nuclear power projects on the development of municipalities in the area. It was found that persons who live in an area where a nuclear power plant actually operates are in support of nuclear power. The remaining respondents, who do not benefit from nuclear power projects in their region, are usually against a nuclear power plant in the area where they live. Respondents (e.g. from the UK) agree that new nuclear power plants could be built in the same location as old nuclear facilities that are dismantled, and respondents who work for the nuclear sector, either directly or indirectly, actually expect that a new nuclear power plant will be built after the old one is decommissioned. The same applies to radioactive waste depositories. On the other hand, the study also indicates that there are signs of clear opposition against the development of nuclear power in Germany.

<u>Organisations opposing the development of nuclear power in Poland and their initiatives</u>

The draft Polish Nuclear Power Programme and its assumptions are clearly in opposition to the assumptions and objectives of a number of environmental organisations that do not accept the development of nuclear power in Poland or anywhere in the world. The one organisation that stands out in particular is a group called Anti-Nuclear Initiative (Inicjatywa Antynuklearna) – it identifies very strongly with anti-nuclear protests in Germany where the police regularly fight with the opponents of nuclear power on the streets or with groups of protesters who block transport routes leading to nuclear power plants. A group of scientists also voice their protests against nuclear power, including a number of scientists who are published in the press.

Arguments against the development of nuclear power in Poland are focused on a number of key areas. The vast majority of these arguments are based on the economic viability of nuclear power projects. Other arguments result from concerns about a possible terrorist attack, a breakdown or a serious accident in a nuclear power plant and the potential environmental pollution that could pose a threat for humans. The example of Chernobyl is showcased regularly, but often based on wrong interpretation of data or even on information that is simply not true. These arguments completely disregard the technological advancement and development of nuclear safety standards. Other arguments include the examples of other countries that do not use any nuclear power or do not build any nuclear power plants.

What is interesting is the fact that many anti-nuclear initiatives that are active on the Internet often remain anonymous (the website of Inicjatywa Antynuklearna is the best example), unlike the supporters of the development of nuclear power (Energetyka Jądrowa website). This makes a serious and constructive discussion difficult.

We should note that the activities of Inicjatywa Antynuklearna and other environmental organisations are often propaganda-like. It applies in particular to the practice of presenting unverified or even false information.

However, some environmental organisations that promote cleaner environment and protection of nature also promote nuclear power. Environmentalists for Nuclear Energy (EFN) are one of them. it was established back in 1996 and now has about 9 thousand members around the world. In Poland, Stowarzyszenie Ekologów na Rzecz Energii Nuklearnej (SEREN) is the leading organisation of this type. Its objectives are to create an association for the supporters of nuclear power for peaceful purposes, and to present to the society the complete and objective information on the power sector and its environmental impacts.

Opinions expressed by Patrick Moore, co-founder of Greenpeace are also very suggestive. Moore changed his mind about nuclear power and now opposes the official position of his organisation. In an article published in 2006 in Washington Post, he states that nuclear power must complement the power generation sector based on renewable energy sources. Of the same opinion are other experienced environmentalists, including Stewart Brand (author of the Whole Earth Catalogue), James Lovelock (originator of the Gaia Theory, member of EFN), or the late British bishop Hugh Montefiore (founder and one of directors of Friends of the Earth). Last year, they were joined by Stephen Tindale who had acted as the Executive Director of Greenpeace in the United Kingdom for many years (from 2000 to 2005). In 2009, he took a U-turn on nuclear power and with a group of other respected British environmentalists expressed his support for the development of nuclear power.

<u>Main barriers to the development of nuclear power – arguments for and against</u>

The development of nuclear power in Poland will encounter a number of barriers: incompatibility of the Polish law, lack of clear vision of the future – how to meet the energy security requirements with the ever-increasing need to protect the natural environment and to meet the society's expectations, and different views expressed by various groups. The relatively low level of public knowledge of nuclear power and opinions based on inaccurate information will be also a major source of barriers.

Presented below is our review of the main problems related to the development of nuclear power in Poland that are discussed by the public and the media. These problems are discussed from the perspective of both the supporters and opponents of nuclear power - for each item, arguments and views for and against are presented. In this way we are trying to ensure an impartial approach to every problem.

Arguments for and against the introduction of nuclear power relating to the feasibility of a nuclear power project in Poland.

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"With the current consumption levels, global resources of uranium will suffice until 2061. However, development of the nuclear power and the ever-increasing consumption of energy may lead to the depletion of uranium resources already in 2030." "The expected bottlenecks in uranium ore supplies may become a more serious problem than we would expect – given the disproportion between countries that extract uranium ore and countries that use it. Of all countries in the world that operate nuclear power plants, only Canada and Republic South Africa are not dependent on uranium imports. The largest 'atomic' countries either do not extract their own uranium ore (France, Japan, Germany, South Korea, Sweden, Spain) or have uranium ore resources that will not be sufficient for their reactors in a longer term (the USA, Russia). If we consider the problem of fuel supply for nuclear reactors, nuclear power cannot be the main source of domestic electricity production almost anywhere in the world. Russia in particular will soon face the first uranium supply crisis. This in turn may affect operators of nuclear power plants in the European Union that purchase about one-third of their nuclear fuel from Russia. China and India may also be forced to cope with a similar crisis if they continue to increase the number of their nuclear reactors, as they have declared."	**Sufficiency of raw materials**	"The available resources of uranium depend strongly on its market price. Until 2001, the price of uranium ore was exceptionally low – about \$20/kgU. It was caused mainly by overproduction of uranium by 1990 and lack of social acceptance for nuclear power, resulting in overstocked inventories of uranium ore accumulated by power utilities. Nuclear disarmament reduced the prices even further by introducing cheap uranium from dismantled nuclear heads to the market. The inventory of uranium that came from disarmament has been almost used up by now, and the threat of a climate disaster put nuclear power back in the picture. As a result, the price of uranium has increased significantly. In 2005-2007, a 'uranium bubble' occurred – a sudden, exponential increase in the price of uranium, up to \$300/kgU. The current price (2009) is settled around \$100/kgU. This trend made it possible to explore uranium deposits that had been considered economically unviable before. With the increased outlays on the prospecting of new uranium ore deposits in 2001-2007, the known resources of cheap uranium increased by 40%. In 2007, the assured uranium resources that could be mined at less than \$80/kgU were estimated at 5,469,000 tonnes. IAEA estimates that these resources will suffice for at least 100 years of operation of nuclear reactors currently used, and the expected discovery of new deposits should extend this time frame up to 300 years. Civil nuclear power sector has been developing for 52 years only.(…). In the next 20-30 years, the introduction of Fast Breeder Reactors (that are currently developed as part of the Generation IV nuclear power programme) will make it possible to use both spent nuclear fuel produced by reactors currently under operation and the resources of depleted uranium left after the enrichment process. As a result, current resources of uranium will suffice for thousands of years." "The security of supply of nuclear fuel for Polish nuclear power plants should not raise any concerns if we adopt the solutions developed in the European Union. Still, when paving the way for the first nuclear power plants in Poland, we

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		must actively follow the situation in the uranium market and fuel cycle services market. When doing so, we should use documentation prepared by the EURATOM Supply Agency and other global organisations (IAEA, OECD/NEA) and participate in the relevant long-term EU projects (especially SNE-TP). The focus on the uranium and fuel cycle services market in the coming years may give us valuable information well in advance as to the resistance of the future Polish nuclear power sector to potential disruptions in the fuel market in its first 'formative' years."
"The question whether radioactive waste can be isolated from the biosphere for hundreds of thousands of even millions of years is a philosophical question. It just goes beyond our imagination. Only 5 thousand years have passed since the pyramids were built, and we must now think about how to safely deposit waste produced by German nuclear power plants in 2010 until 10010 or even 100010. But we have no choice: because nuclear waste does exist and we cannot be 100% certain about the answer to this question, we must develop the most optimum technical solution to the best of our today's knowledge." "In 2000, the amount of spent nuclear fuel deposited in the world totalled 220,000 tonnes. This amount increases at a rate of about 10,000 tonnes every year. Still, although many methods of deposition of spent nuclear fuel have been analysed for the past decades, including its deposition in space, the nuclear power industry has not found a solution to this problem yet. Most proposals for the management of highly radioactive waste involve its deposition in deep geological formations. However, there is no way of saying if the containers, the depository itself, or the surrounding rocks will ensure a sufficient barrier against radiation. The Yucca Mountain repository in Nevada, the USA, is one example of a failed nuclear waste deposition project. After twenty years of analyses and billions of dollars spent on the project, not even one gram of spent nuclear fuel was deposited in Yucca Mountain. The very fundamental questions regarding the geological feasibility of this	**Deposition of radioactive waste**	"...highly radioactive waste is deposited deep under ground, e.g. at the depth of 500 meters, and radiation is no problem as long as its stays there – only several meters of the ground are enough to reduce radiation to undetectable levels. The only risk is the potential corrosion of containers caused by water, which may wash radioactive waste out of glass in which it was vitrified and move it up towards the surface and sources of potable water. Radioactive waste may become a threat only when ingested by humans. But, as an example, salt deposits would dissolve in water long time ago if water was able to penetrate through to them. And salt is dissolved in water much faster than glass! If we deposit containers with nuclear waste in salt layers, we can be sure that water cannot get through to them. But for how long? For much longer than the period during which nuclear waste remains hazardous. Our life is short compared to half-life of some radioisotopes, but geological changes take much longer time. The rate of removal of vitrified nuclear waste from glass will be slow, because methods of containment of waste used by the nuclear power industry are very effective. As a result, waste will be separated from the biosphere for a very long time, and even if it is removed from glass, the infiltration rate will be very slow. Moreover, the storage of nuclear fuel in tight containers will separate it from the environment for thousands of years! It is technically feasible and not difficult – the nuclear power industry is ready to build this type of depositories for radioactive waste in a number of countries.

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area were never answered. On top of that, it was discovered that scientific data had been manipulated, which triggered an investigation. Problems with radioactive waste deposition are not limited to highly active waste (i.e. the most radioactive waste generated in a reactor, which can cause death on exposure). There are many examples of depositories for low-active nuclear waste that are a source of harmful radiation. Drigg in the UK and La Hague in France are just two of them. Nuclear waste emits radiation for tens, or even hundreds of thousands of years. No human language has survived for more than several thousand years, and no one can tell whether pictograms or other symbols will be interpreted correctly in the future. Therefore, there is no way of ensuring that the future generations are warned about radioactive waste repositories.		How much land is needed to deposit highly radioactive waste? According to the EU studies, if nuclear power plants with the capacity of 30,000 operate for 60 years without breaks and at full capacity, they will produce 5400 cubic meters of high-active nuclear waste (after reprocessing of spent nuclear fuel). After this waste is vitrified and closed in cylinders (22 cm in diameter and 110 cm high), it may be deposited in 600 openings drilled in the area of just 0.4 square kilometers.
Nuclear power plants are an attractive target for terrorist and military attacks, given their importance in the power sector, threats resulting from the release of radioactive substances, and their symbolic meaning. An attack targeted against a nuclear power plant may result in a disaster several times more serious than in Chernobyl. Nuclear facilities may be attacked during wars if they are allegedly used for military purposes. They may be attacked in a variety of ways – from the sea, land, or air. There is evidence that more and more terrorist groups are considering potential attacks on nuclear facilities. In this context, the decision of the nuclear power industry and governments of some countries to increase the number of nuclear reactors worldwide is a sign of their stupidity and recklessness. "We may also assume with 100% certainty that none of the 436 reactors used at the beginning of 2010 around the world would withstand a targeted attack of a filled-up wide-body jet aircraft. In Western industrialised countries the risk of accidental crashes of small passenger or military aircraft was taken into account when building many nuclear reactors. However, accidental crashes of filled-up large passenger aircraft were considered so unlikely that this scenario was not assumed by any country in the world and no	**Terrorist attack**	"It may seem that nuclear facilities (including power plants) are an easy target for terrorists – it is enough to plant a bomb, throw a hand grenade, or crash an aeroplane. But in reality, nuclear facilities ensure ***the best possible protection against potential terrorist attacks*** – much better than for example chemical plants, water intake points, or coal-fired power plants(…). The system of protection of nuclear materials and facilities is a combination of administrative measures and a number of different types of physical barriers. This system consists of many interrelated elements: procedures for the personnel, methods of operation of equipment, plans of location of physical barriers in the expected sensitive areas in the facility, etc. (...).Terrorist attacks in New York proved that an external attack is easy. Therefore, certain measures are now more commonly introduced to prevent terrorist attacks such as destruction of physical barriers with armoured fighting vehicles filled with explosive materials, or a similar attack from the air or (potentially) the sea (as in Japan) in cases where nuclear facilities are located on coastal sites. In these cases, special coastal patrols are organised. Although a number of factors that may potentially lead to a nuclear accident have been considered since the early years of nuclear power,

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effective procedures were developed. A planned attack using a passenger aircraft as a targeted missile was beyond the limits of imagination of nuclear reactor designers.”		analyses indicate that older nuclear facilities that had been built in countries that used Soviet technologies, as well as the first nuclear reactors built in Western countries whose structural elements were affected by natural degradation, are not 100% resistant to this type of attacks. There are in urgent need of upgrades, just as certain facilities located near airports. In the United States, the mandatory safety zone of 10 miles around the reactor was introduced. If the damage caused by a terrorist attack is limited to one function or a single component of a nuclear reactor (e.g. a breakdown of the primary loop cooling system or external power failure), small corrective action will minimise this damage to a large extent. However, the situation is more serious if a number of elements are damaged. Structural design of a reactor building plays a major role in minimising the impact of a potential terrorist attack targeted at a nuclear facility with a reactor (power plants, research centres) – both external attack and internal sabotage. New buildings that house a reactor core have double walls (nearly 1 meter wide) made of reinforced concrete (with a free space of about 2 m between the walls that is monitored on an on-going basis) and additionally reinforced with a steel wall (several centimetres wide). The structure of this wall is similar to a ship’s hull. Inside the building, a reactor core is placed in a safety containment made of steel and reinforced concrete (several meters wide). Simulations have proved that **this structure can be damaged from the outside only by a major nuclear explosion.** This structure will withstand strong earthquakes and hurricanes (the Three Mile Island facility in the USA survived a 6.7 earthquake (the Richter Scale) and hurricanes with wind speed of 200 miles/h).”
“It was calculated that a nuclear power plant emits 1/3 of CO2 (a greenhouse gas) compared to a modern gas-fired power plant with the same capacity. However, this ratio will be multiplied if we add emissions of greenhouse gases from deposited nuclear waste and from nuclear decommissioning after the nuclear power plant is closed. Highly radioactive waste	**Nuclear power vs. climate**	“Nuclear power plants have a lower negative impact on the natural environment than other commonly used sources of energy. They do not generate greenhouse gases, do not release pollutants to the atmosphere, and they produce waste that is deposited in safe locations and subject to close monitoring. We often see huge clouds of smoke

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must be cooled down 24 hours a day, for thousands of years! One of the methods of management of low- and medium-active nuclear waste is to build underground repositories in rocks for concrete or steel containers with nuclear waste. All these energy-intensive processes are a source of greenhouse gases. Therefore, the relative benefits that may be expected only assuming a failure-free operation of nuclear power plants (which cannot be guaranteed), are neutralised by the damage caused by GHG emissions." "Nuclear energy is the most expensive and most dangerous of all types of energy. The risk of proliferation of nuclear weapons, the problem of radioactive waste, the possibility of breakdowns and threat of terrorist attacks – these factors make it an unviable alternative. It is high time we stopped wasting public money on 'dirty' technologies and focus on renewable energy sources that are the only way to stop climate changes".		released from smokestacks in nuclear power plants – but it's not pollution, just water vapour free of any pollutants and completely neutral to the natural environment. In addition, nuclear power plants do not deplete valuable resources that can be used for other purposes. Moreover, they are able to generate high capacity using a relatively small area. The nuclear power sector helps protect the environment by eliminating about 2.4 Gt (2,400,000,000,000 kg) of CO2/year. Obviously, nuclear power will not eliminate CO2 emissions altogether, but it sets the direction – how not to increase GHG emissions, at the very least. Just as an example: a coal-fired power plant with the capacity of 1000 MWe uses from 2 to 6 million tonnes of fuel per year (depending on the type of coal), and at the same time produces and releases 6.5 million tonnes of CO_2 (960 t CO_2/GWh) to the atmosphere. A similar gas-fired power plant uses 2 to 3 billion cubic meters of gas and produces 480 t of CO_2/GWh. An oil-fired power plant will use 1.5 million tonnes of fuel oil and produce 730 t of CO_2/GWh. A biomass plant with the same capacity will need an area of 6000 square kilometers as a source of biomass, a wind farm will cover an area of 100 square kilometers, and a solar power plant - 50 square kilometers. Unlike these facilities, an emission-free nuclear power plant with the capacity of 1000 MWe will use only 35 tonnes of fuel per year and will cover only several square kilometers. In the European Union alone, nuclear power plants reduce CO2 emissions by about 700 million tonnes per year, which equals the total CO2 emissions produced by all cars owned by citizens of all Member States."
"The CapEx of a nuclear power plant construction project assumed in the Programme (3.0-3.3 billion euro/1000MW) is not up-to-date. Data presented by power utilities and rating agencies put the figure at 4.5 up to 5.4 billion euro/1000 MW. This data is confirmed by EDF. In its published results for Q2 FY 2010, EDF informed about the increase in the cost of construction of a nuclear power plant in Flamanville, France - from 3.3 to 5 billion euro. It suggests that the CapEx for nuclear power plant projects assumed in the Programme is	**Costs of nuclear power**	"The cost of electricity generated in a nuclear plant is 35 euro/MWh, in a coal-fired plant – 64.4 euro/MWh, in a gas-fired plant – 59.2 euro/MWh, in a peat-fired plant – 65.5 euro/MWh, and in a wood-fired plant – 73.6 €/MWh (wood is not subject to the CO_2 tax). Wind farms can supply electricity at the price of 52.9 euro/MWH assuming that they work at full capacity for 2,200 h a year and bear no costs due to discontinued operation. In a nuclear power plant, investment outlays are the key element of costs, and the cost

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underestimated by as much as 60% and does not reflect the real costs of their construction. CapEx translated into electricity depends to a large extent on the interest rate on borrowings and the period of repayment of the construction loan. As nuclear power plants are commercial projects, cost analysis is based on data assumed for a typical commercial loan for the construction of a power plant. If we assume the interest rate on a loan at 7% and return on equity at 10.5% (1.5 x borrowing costs), and 70% of funds coming from borrowings, the average cost of capital will reach 8.05%. The cost of capital per 1 MWh of electricity produced in a nuclear power plant depends on the loan repayment period. Typically, loans are granted for 20 years, of which 5 years for construction and 15 years for operation of the project. In order to take out loan for a period longer than 20 years, especially for the construction of a nuclear power plant, state guarantees will be required. Still, even if a state guarantee is secured for the nuclear project and the period of loan repayment is extended, which is not possible under regulations currently in effect, this project will be economically unviable compared to other technologies. For a 20-year period of loan repayment, CaPex will reach 100 – 80 PLN/MWh for coal-fired power plants, 65.64 PLN/MWh for gas-fired power plants, and 282.61 PLN/MWh for nuclear power plants. For a 50-year period of repayment, these costs will reach, respectively: 66.90, 43.48 and 195.45 MWh – that is, three times higher when compared to coal-fired power plants and five times higher compared to gas-fired power plants. The Programme says virtually nothing about the operating costs in nuclear power plants. The complex technology and stringent safety requirements increase the OpEx in nuclear power plants. According to data from US nuclear power plants where production is managed at a very high level, these costs amount to 138 PLN/MWh. However, we must take into account total costs. Calculations were based on the following assumptions: 1 euro = 4 PLN, CO_2 = 30 euro/Mg, fuel cost: black coal - 11.5 PLN/GJ; brown coal – 6.7 PLN/GJ; gas – 320 USD/1,000 mJ, nuclear fuel – 12.5		of nuclear fuel is low. For other power plants, costs of fuel are the main cost component. Wind farms are an exception to this rule. In wind power plants, CapEx per one unit of peaking capacity is two times lower than in nuclear power plants, but much higher per one unit of average capacity during the year. "Total cost of coal and CO2 emissions will reach **413 million euro/year**. This figure is much higher than in a nuclear power plant, but CapEx in a nuclear power plant is much higher compared to coal-fired power plants. In the Flamanville nuclear power plant, CapEx amounts to 2450 euro/kW, i.e. **3266 USD/kW**. We should note that the Flamanville 3 project is implemented without delays and in accordance with the adopted budget. The CAPEX of the first nuclear power plant in Poland may be higher than in nuclear power projects currently implemented in France, but to compare a number of plants we should assume average the CAPEX typically assumed around the world. The latest estimates of OECD assume 2.75 billion euro per 1000 MWe. For the second and every subsequent nuclear power plant in Poland, we may assume the positive effect of the learning curve in the nuclear power industry and lower investment costs. However, we will assume the worst-case scenario – CaPex will be higher than the latest OECD estimate and will be equal to CaPex of the second unit in the Florida nuclear power station in the USA – ***3220 €/kWe.*** These investment costs are higher than in Flamanville 3, because CAPEX in the USA is always higher than in Europe (by about 20-30%) – not only for nuclear power projects, but also for coal-fired power plants. Therefore, CAPEX assumed at 3220 €/kWe gives us a large safety margin. For coal-fired power plants in Poland, prices in 2008 reached from 1800 €/kWe to 2000 €/kWe. We will assume the cost of 1875 €/kWe, just as for the new power plant in the former Czeczot coal mine. The resulting difference in CapEx for the second and every subsequent nuclear power plant in Poland amounts to 1345 €/kWe. This is an amount equal to the difference in fuel costs and CO2 emission charges

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USD/MWh. These figures indicate that nuclear energy is the most expensive type of energy and its cost reaches nearly 100 euro/MWh with a very long period of loan repayment. It is over two times higher than assumed in the Programme. Publication of underestimated costs of electricity production in nuclear power plants may be interpreted as an attempt to mislead the public opinion.”		that must be incurred when burning imported coal instead of nuclear fuel during a 4-year period. Obviously, these findings should not be interpreted as a complete economic calculation, only as an illustration presenting the key elements that determine the final cost of electricity produced in nuclear and coal-fired power plants. As we can see, thanks to very low cost of nuclear fuel, **nuclear power is an economically viable alternative despite the high capital expenditure.**”
“We don’t need a nuclear accident to release radioactive substances to the air, water and soil. Day-to-day operation of a nuclear plant is enough – and these emissions are allowed pursuant to the Government’s regulations. Radioactivity is measured in the curie (Ci). 1000 medical laboratories that use radioactive isotopes will contain the equivalent of 2 Ci. In comparison, an average reactor core will contain about 16 billion Ci, which is equal to long-term radiation from at least 1000 atomic bombs dropped on Hiroshima. Piping, valves, and tanks in a reactor may have leakages. Leakages can be also caused by mechanical breakdowns or human errors. Ageing affects the entire reactor and its individual components, and leakages are more frequent with time. A portion of contaminated water is discharged on purpose from the reactor pool to reduce the amount of radioactive substances and corrosive compounds that would otherwise destroy valves and pipes. This water is filtered and returned to the cooling system or released to the environment. A typical 1000 MW nuclear power plant with a PWR and a cooling tower needs 80 thousand litres of water from a river, lake or the sea per minute for cooling. This water is transported through 80 km of pipes. 20 thousand litres per minute are discharged back to the source, and the rest is released to the atmosphere as water vapour. A 1000 MW reactor without a cooling tower needs even more water - up to several million litres per minute. After circulation in the plant’s loops, water is released to the environment. It is	**Radiation in the area of nuclear power plant**	“In the Flammanville nuclear power plant in France with two PWRs with the capacity of 900 MWe, the typical dose of radiation from all emissions from this power plant is 0.0003 mSv/year. The Souleau Commitee appointed by the French government determined that the maximum doses of radiation corresponding to the allowed limits would amount to 0.3 mSv/year, and the actual dose of radiation measured outside of the power plant reached 0.01 mSv on average, i.e. 30 times lower than the adopted limits and 200 lower than the dose coming from natural background radiation. Also in the USA, the average radioactive emissions from all nuclear power plants are much lower than the acceptable maximum levels. Negative health effects caused by these low emissions have never been determined, and it is expected that they will never occur. Despite the claims presented in publications by anti-nuclear activists, a study by the US National Cancer Institute conducted on a wide scale (500,000 persons) confirmed that there are no signs of the increased cancer rate in the vicinity of nuclear power plants in the USA. Poles should not think that results recorded by the Swiss, Germans or Americans are beyond our reach due to some differences at the level of technical culture or social conditions. In the neighbouring country of Slovakia, a nuclear power plant was built in late 1980s with two WWER-440 reactors (similar to those planned in the Żarnowiec power plant in Poland). The political changes in Slovakia put the Mochovce project on hold for a couple of years, but the project was never abandoned and finally both reactors were put into

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contaminated with radioactive elements – their concentration is not known and it is difficult to measure, but it does affect our lives. Some radioactive gases removed from cooling water are contained in waste gas decay tanks before they are released to the atmosphere through fans fitted with filters. Some gases are released inside the nuclear power plant buildings and are removed from time to time during what is known as 'airing'. These free gases will contaminate not only the air, but also water and soil. Radioactive leaks from a nuclear reactor that occur during normal operation are often not fully detected and not reported. Emissions caused by nuclear accidents may not be verified or documented in full. For certain key side-products of a nuclear reactor (radioactive hydrogen – tritium, noble gases such as krypton and xenon), there are still no effective and economically feasible techniques of filtering and monitoring. Some liquids and gases are kept in containers to allow for the decay of less permanent radioactive materials before they are released to the environment. Regulations currently in force approve the release of radioactive water that contains 'acceptable' concentrations of pollutants. But 'acceptable' does not necessarily mean 'safe'. Detectors installed at reactors are set up to allow the release of unfiltered water that contains more pollutants that 'acceptable'. Detection of leakages and predicting the spread of radioactive pollution by US Nuclear Regulatory Commission is based on reports and computer models provided by operators of nuclear power plants. A large part of the environmental monitoring data comes from extrapolation instead of actual observation. We just do not have the accurate data for the entire amount of nuclear waste released to the air, water and soil during all phases of the nuclear power production process. This cycle includes: extraction and processing of uranium ore, chemical processing, enrichment, production of fuel, nuclear reactors, as well as pools, trenches, and barrels where nuclear waste is kept. The ever-increasing economic pressure on cost cutting triggered by the deregulated electricity production industry may further		operation – after the introduction of certain modifications. These reactors now produce electricity that is 50% cheaper than electricity produced in conventional power plants, and at the same time they meet all safety requirements adopted in the EU. Radiological analyses indicated that doses of radiation in the area are so small that they cannot be even measured. When measurements were finally taken, it turned out that in the period of 6 years since the opening of the Mochovce nuclear power plant, additional annual doses of radiation from this facility never exceeded one MILLIONTH of a Sievert (ranging from 0.1 to 0.7 micro Sv)."

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undermine the effectiveness of monitoring and leakage reporting systems (that is already questioned). Delayed upgrades may increase the emissions of radioactive substances and the resulting risks. Many side-products of nuclear reactors are able to emit radioactive particles and rays for a very long time – defined based on their 'half-life'. Radioactive materials will emit harmful radiation for at least 10 half-lives. The half-life of one of iodine isotopes (iodine-129) is 16 million years; the half-life of technetium-99 is 211 thousand years, and of plutonium-239 – 24 thousand years. Xenon-135 (noble gas) will decay to caesium-135 – a long-lived isotope with the half-life of 2.3 million years.` It is a scientifically proven fact that low-level radiation damages our tissue, cells, DNA, and other vital molecules, and causes the gradual cell death (apoptosis), genetic mutations, cancer, leukaemia, birth defects, as well as disorders of our reproductive, immune, and secretive systems."		
"Polish nuclear power plants will pose a threat of another Chernobyl disaster. The system selected by the Polish government is so hazardous that the British decided to ban the construction of this type of reactors. Polish experts are inexperienced and take producers at their word - said a renowned expert in nuclear energy as a word of caution. "The British Nuclear Installations Inspectorate refused to approve the EPR project (European Pressurised Reactor with the capacity of 1600MW) based on safety concerns", explained prof. dr hab. inż. Władysław Mielczarski, professor ordinarius at the Technical University of Łódź, member of the European Energy Institute, in his publication in Wirtualny Nowy Przemysł. And British experts are among the most experienced nuclear energy experts in the world. They claim that reactors that Poland intends to purchase have major safety issues. including the maintenance of the optimum temperature and pressure. And when these problems arise, a nuclear power plant cannot be stopped immediately. According to prof. Mielczarski, the problem of safety of nuclear reactors is not	**Safety**	"Since the very beginning of nuclear power, nuclear power plants in Western countries have been designed in such a way as to ensure that the effects of any potential (even very unlikely) accident do not exceed the acceptable level. A number of different and reliable safeguards were used, mainly based on natural mechanisms such as the force of gravity, safety systems with three or four redundant subsystems, large safety margins assumed in the design, and many other design and organisational measures described in the article titled "Protection against hazards after breakdowns in nuclear power plants" published in the September issue of PSE Bulletin. For design-basis accidents, it was assumed as a rule that safety systems in a nuclear power plants must be sufficient to control the accident in any given element of the plant, even if the accident occurs in the most difficult location from the operator's perspective and in the most adverse conditions, and will be accompanied by a single additional failure in any given system in the nuclear power plant, also in a system that is supposed to control and contain this very accident. Based on these assumptions, designers of nuclear power plants had to make plans for the worst-case scenario and the most

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discussed in Poland at all, and the government presents them as a super-safe solution. "Some time ago, people were convinced that they had built a super-reliable machine. It was a ship – and her name was the Titanic. Since that time, nothing has been called super-safe or reliable. When I hear lobbyists singing praises about the safety of nuclear reactors, it is worthwhile to stop and think - maybe they are trying to sell us a ticket for the new Titanic?", said prof. Mielczarski. He suggests that Polish experts have no experience in this area whatsoever. They have completed one-week courses and information from producers is all they have to rely on. And this information is not always true. That is why the decision regarding the selection of a particular type of a nuclear reactor for Poland in 2010 must be well prepared. Otherwise, the new Polish nuclear power plants may destroy Poland."		adverse conditions – for instance, loss of power supply from an external network (irrespective of the additional single failure in any system in the nuclear power plant), and prove that the existing safety systems are sufficient to shut the power plant down, cool it down, and prevent the release of radioactive substances. We did witness one accident in a nuclear power plant that included a PWR core meltdown. It happened during a nuclear accident in the Three Mile Island (TMI) nuclear power station, where the power supply was not interrupted, but wrong decisions taken by operators caused the failure of the emergency core cooling systems and melting of the nuclear fuel. However, although the core and the entire nuclear reactor had been damaged to such an extent that the subsequent repair of the nuclear power station was not possible, the reactor pressure vessel maintained its integrity, and the safety containment prevented the release of fission products – as a result, the doses of radiation outside the nuclear power plant were negligibly small. Nobody lost their life or health as a result of the TMI accident. The TMI case proves that even 'old' reactors have safety margins that will ensure the containment of the effects of beyond-design basis accidents involving the nuclear core meltdown. At the same time, the TMI accident serves as a warning – human error is possible and fast and effective interpretation of the emergency processes may be difficult and may lead to very wrong decisions. Therefore, analyses were launched to determine whether effective rules of procedure can be developed to prevent human error on the part of operators. At the same time, additional safeguards were introduced to the planned and existing reactors to contain the release of radioactive substances in the worst-case scenario of the most serious hypothetical accidents. There works took many years, and the resistance of nuclear power plants to beyond-design basis accidents have improved over time. At the end of the 20th century, the EU Member States adopted the practice that safety features and systems in a nuclear power plant should be able to contain not only design-

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		basis accidents, but also beyond-design basis conditions in order to prevent the release of large amount of radioactive substances outside of the safety containment. Now, after 25 years since the TMI accident, both the EU and the USA have developed state-of-the-art reactor designs (Generation III reactors) that will guarantee safety for inhabitants of the local area even in the event of serious nuclear breakdowns with nuclear core meltdown.”

1.10 Review of alternatives to the solutions presented in the Programme

Alternative solutions for energy security

In Poland, electricity is generated mostly in coal–fired power plants (as much as 92%) – using both black and brown coal. In the EU, electricity is produced in nuclear power plants (28%), coal-fired power plants (27%) and gas-fired power plants (23%), as well as from renewable energy sources (18%). Poland clearly needs to diversify its energy sources in order to reduce environmental pollution and consumption of coal, and to ensure reliable supply of electricity.

Energy conservation (improvement of energy efficiency) is one alternative to the increase in electricity production volumes. Saving of energy is necessary and brings benefits, but it is possible only to a limited extent, because increased consumption of electricity is a pre-condition for the dynamic growth of any country.

Another alternative is to use renewable energy sources (RES) that must be developed under the obligations assumed by Poland. However, these technologies are expensive, and their energy-generating capacity in Poland is very limited. Hydroelectric power plants are the most commonly used source of renewable energy nowadays. Despite minor negative environmental impacts (related to the modification of the natural river system), hydroelectric power is the most environmentally-friendly source of energy, but their development potential is also rather limited. It is expected that by 2030 it will be used in 100%. Biomass and biogas burning is a method that uses local materials, including waste materials, to produce electricity. Development of this type of RES facilities has a positive impact on the local community (new jobs, market for local products, economic revival of the region). However, also in this case the electricity production potential is limited by the limited volume of biogas and biomass that can be produced (without the excessive reduction of the production of foodstuffs). The Polish Energy Policy until 2030 assumes the highest possible utilisation also for these sources of renewable energy. Wind farms have the widest scope of negative impacts. They are related mainly to the intermittent operation of wind turbines depending on the wind, and the fact that it is impossible to store electricity produced in wind farms (when the wind is gone or when stronger winds start, it is simply not possible to switch the wind farm on or off – they must operate continuously to secure the supply of electricity). Wind farm projects are also very expensive and material-intensive, and require a large area. Electricity produced in wind farms is therefore more expensive and the price is paid by consumers. In general, costs related to the introduction of renewable energy sources are much higher than costs of nuclear power. It is a common misconception that RES offer ‘free’ energy in a way, because its comes from ‘free’ sources such as solar energy or wind power. However, to produce this energy it is necessary to built projects with relatively limited efficiency, and their manufacture, transport, operation, and decommissioning also deplete natural resources and release certain amounts of emissions to the environment. The most fundamental problem concerning the large-scale use of RES is the fact that there are no technologies for the effective and efficient storage of energy, and renewable energy sources (especially wind power) produce electricity in an intermittent manner. Introduction of excessive amounts of electricity to the power grid will destabilise the system of electricity generation and transmission. However, some of these technologies may be unrivalled at a local level where electricity is consumed 'on the spot' and long-distance transmission is not necessary. If this is the case, transmission losses are reduced, as is the demand of individual consumers for electricity from the power grid, thus reducing the overall demand for electricity and the growth in electricity production volumes in the country.

Another alternative is to modernise the conventional energy production sector in order to increase its efficiency and reduce emissions to the environment. Implementation of technologies that reduce the emissions of pollutants to the atmosphere is expensive, and new technologies are implemented very slowly. But their further development is necessary, considering that even if the Polish Energy Policy until 2030 is implemented in its entirety, still 47% of total volume of electricity in Poland will be produced in coal-fired power plants in 2030 (according to the Programme). Therefore, the development of methods that will minimise their negative impacts on the environment is more than justified. .

We can conclude that the necessary modernisation of the Polish energy sector should not be limited to the introduction of nuclear power, as assumed in the Programme, but should also involve the development of RES (in an appropriate scale), investments aimed at the reduction of electricity consumption (energy efficiency projects), and modernisation of conventional energy sources (state-of-the-art electricity generation technologies and the so-called 'clean' coal technologies). Considering the requirements related to the reduced emissions of greenhouse gases and the ever-growing demand for electricity, it is necessary to adopt a policy that promotes all these alternatives, as soon as possible. However, introduction of the Polish Nuclear Programme is still the key element of this policy, in the context of the necessary reduction of GHG emissions, diversification of energy sources, and reduction of electricity production costs. This solution is justified by the fact that of all energy sources, nuclear power has the largest potential to reduce negative environmental impacts at the lowest implementation costs. Therefore, if the overriding objective of the current energy strategy is to reduce emissions and ensure sustainable energy security combined with the reduction in social costs of electricity production at the lowest implementation costs possible, the development of nuclear power is the direction we should take.

Technological alternatives

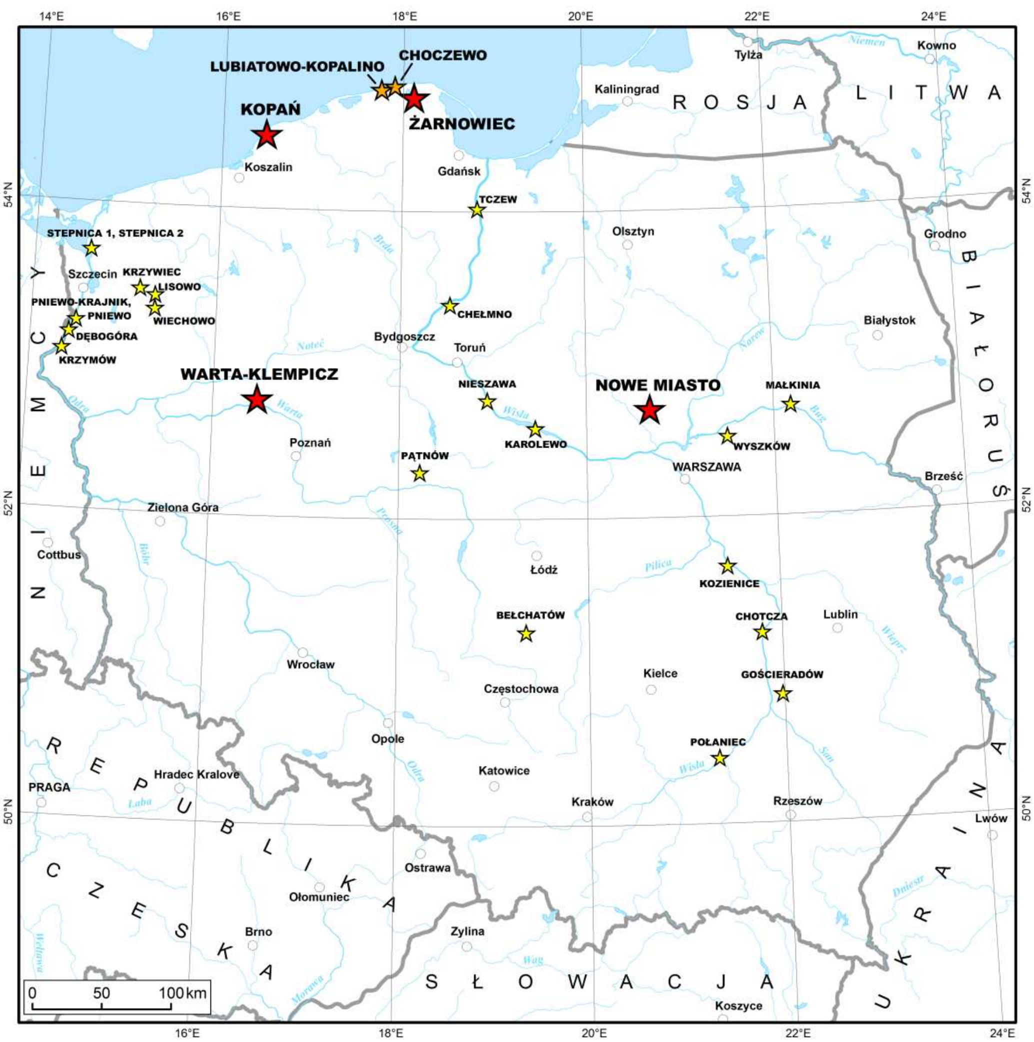
This Report analyses different environmental impacts resulting from the potential use of different types of new-generation nuclear reactors. These reactor types differ in terms of the volume of radioactive emissions (but all of them generate emissions much lower than the adopted standards during normal operation), energy generation parameters, consumption of cooling water, and land take. A number of alternatives for the cooling technologies were also discussed – with or without cooling towers. These systems have different environmental impacts in terms of the demand for cooling water, release of waste heat to the air or water, emissions of chemical substances to the air or water, emissions of noise, and impact on the landscape. An alternative solution involving the utilisation of heat produced in a nuclear power plant was also considered. This solution would reduce a number of negative environmental impacts related mainly to the release of heat to the atmosphere and water. Combined energy sources (producing electricity and heat at the same time) offer higher efficiency in the use of primary energy, which has a positive impact on natural resources. Therefore, it is a highly recommended alternative from the perspective of environmental protection.

At this stage of the SEA Report, we are not able to specify the most viable technological alternative as this decision will depend to a large extent on the actual location for the project. Combined generation of electricity and heat in the planned nuclear power plant should be the recommended alternative, but its viability will depend on the sufficient number of potential customers for heat. As regards the choice of different types of reactors and different types of cooling systems, the final decision should be taken at the public procurement stage on the basis of the Best Available Technology principle, considering the many aspects of their environmental impacts, dependency on the actual location, and the continuous advancement in reactor design technologies.

Location alternatives

Potential locations of nuclear power plants in Poland were selected by the Ministry of Economy based on a list of possible locations considered before 1990 and subsequently updated in consultation with local and regional authorities. The list includes 28 potential sites for the location of nuclear power plants, classified as recommended, backup, and other locations. They are presented in the following map:

POTENTIAL LOCATIONS FOR NUCLEAR POWER PLANTS



recommended locations

backup locations

other locations

To make the choice of the most optimum location easier, a multi-factor analysis was performed for environmental impacts and technological options for recommended, backup, and other locations. The analysis of potential environmental impacts of the planned investment was based on: number of towns and villages in the restricted-use area; energy efficiency of wind; close vicinity of protected landscape areas; risk of land take and potential restriction of access to natural resources; potential impact on the cultural heritage; and impact on plants and animals. In addition, the analysis included technical factors related to the access to water resources during the technological process, and possibility of connection to the transmission network.

The analysis of recommended locations and backup locations as regards the expected restricted-use area indicated that resettlement of people will be necessary only if the nuclear power plant is built in Nowe Miasto. The analysis conducted for the remaining sites showed that in two other cases (Połaniec, Chełmno) resettlement of people is possible in two towns/villages, and resettlement of one town/village is possible in Karolewo, Kozienice, Małkinia, Wyszków, Pątnów, Krzywiec, Pniewo-Krajnik, Nieszawa, and Chotcza. In other locations, resettlement will not be necessary.

Analyses of wind power zones indicated that wind conditions are good and very good in all recommended and backup locations, which will ensure that potential emissions of pollutants from nuclear power plants will not accumulate in one area.

Analyses also considered the close vicinity of protected landscape areas and the potential negative impact of nuclear projects on these areas. National scenic areas (Landscape Parks) are situated in recommended locations near Żarnowiec and Choczewo, but at a sufficient distance to reduce the potential risk of deterioration of their scenic value. As regards backup locations, only the town of Chełmno is situated in the central part of a Landscape Park. Chotcza, Karolewo, Kozienice, Małkinia, Wyszków, Lisowo, Wiechowo, Pniewo, Pniewo-Krajnik, Dębogóra, and Krzymów are located at a short distance. Other locations are situated away from protected landscape areas.

As regards the local natural resources base, no limitation of access to mineral deposits and their exploration was determined during analyses. Natural resources were found in the vicinity of several towns and villages: brown coal (Bełchatów, Nieszawa), rock materials (Gościeradów, Karolewo, Pątnów), and chemical materials (Stepnica 1 and 2, Połaniec). However, given the considerable distance from the planned sites, access to these resources should not be limited.

Geological and hydrological conditions are an important factor, including in particular the parameters describing the rate of water infiltration. They are of key importance when water and ground is contaminated and pollutants may go through to rock formations. The location analysis indicated very diversified geological and hydrogeological conditions in different locations. The planned locations are characterised by low or very low sensitivity to groundwater pollution. Only the Żarnowiec site is very sensitive to the potential contamination of groundwater. In backup locations, the most unfavourable hydrogeological conditions were found in Kozienice, Wyszków, Pniewo, Pniewo-Krajnik, and Dębogóra. These sites are very sensitive to potential contamination of groundwater. The best hydrological conditions were found in Tczew, Nieszawa, Bełchatów, Karolewo, and Małkinia.

Close vicinity of cultural assets and archaeological sites is another factor analysed in this Report. As regards the recommended locations, works should be conducted under archaeological supervision only in one location (Lubiatowo – Kopalino), given the vicinity of archaeological sites. In other locations, archaeological sites are located at a safe distance from the construction site or have not been documented in the area. Archaeological sites are found in the close vicinity of certain backup locations (Chełmno, Gościeradów, Karolewo, Połaniec, Pątnów, Krzywiec, Lisowo, Wiechowo, Dębogóra), and the planned project may have a negative impact on these sites. In other locations, we do not expect any risk to cultural assets and any conflict between cultural heritage and the planned project in the construction stage, or any delays if the project is suspended for the period of archaeological works.

Our analysis of the potential utilisation of cooling systems in a nuclear power plant in recommended locations shows that sufficient water resources are found in all cases. In addition, an open–circuit cooling system is recommended for Kopań, Choczewo, Lubiatowo – Kopalino, and a closed-loop system is recommended for Warta – Klempicz and Nowe Miasto. Żarnowiec will use either an open-circuit or a closed-circuit system, depending on the technical solutions adopted. The analysis of backup locations indicated that with the exception of Krzywiec, Bełchatów, Lisowo, and Wiechowo, the existing water resources are sufficient for the planned processes. In Bełchatów, the existing resources are either insufficient or the planned cooling system concept has not been defined. Based on the analysis of the proposed cooling system alternatives, an open-circuit water cooling system was proposed for the following locations: Chełmno, Nieszawa, Karolewo, Tczew, Stepnica 1 and 2. A closed-circuit water cooling system was proposed for: Gościeradów, Chotcza, Kozienice, Małkinia, Wyszków, Połaniec, Pniewo, Pniewo-Krajnik, Dębogóra, and Krzymów.

Analysis of the potential connection to the existing transmission network indicates that four out of six planned locations are worth considering, and further detailed analyses are needed. Warta – Klempicz is the top recommendation here. On the other hand, the location of Nowe Miasto is especially unfavourable – mainly due to the lack of network infrastructure in this region of the country, with no plans for its development in the nearest future. As for backup locations, the following are recommended: Chełmno, Karolewo, Kozienice, Tczew, and Połaniec. The remaining locations are not recommended.

One additional aspect considered in the analysis are the potential threats to the planned location of the nuclear power station. The identified threats included a possible building disaster in the Włocławek dam whose technical condition has deteriorated (Nieszawa, Karolewo) and a possible explosion in the planned high-pressure pipeline (Gościeradów).

Among backup locations, Bełchatów seems to have the least negative impacts on the fauna and the areas of nature protection. The diversity of animal species in this particular location is rather low and it is not close to any protected areas that could be affected. On the flip side, this location will interfere with the network of ecological corridors. The proposed location in Połaniec is difficult to evaluate – it could be classified in a similar way as Bełchatów, but it is located in the Vistula valley. There is no published data on the biodiversity of animal species in this location, but it may as well result from the fact that its natural value is slightly less attractive compared to other section of the Vistula valley. The problem is that even the relatively less diverse ecosystems of river valleys are still usually much more diverse than the common ecosystems in agricultural and woodland areas. Therefore, this location should be approached with caution and further detailed analyses are needed. Other locations are situated within Natura 2000 sites or in their close vicinity, and some are situated near bird migration routes and interfere with the network of ecological corridors.

Based on the adopted method of evaluation of the diversity of plant cover on the basis of the number of plant species recorded in published sources and types of habitats in individual locations, their representative comparative analysis was possible. Significant differences between individual locations were highlighted. The plant cover diversity is the lowest in the location of Nowe Miasto (central lowlands). This location stands out, both in terms of the plant cover and habitats, and as regards the lack of any forms of nature protection – which means that there is nothing to protect in this location. especially in comparison with other recommended and backup locations, four of which are situated in the coastal area where a large number of rare and protected taxa are found (both plant species and habitats). Coastal sites are also surrounded with many forms of surface protection areas. The location in Nowe Miasto is therefore the most optimum location if we want to minimise the potential threats to the existing plant cover. Of all backup locations, Bełchatów has the lowest diversity of plant species. It is situated far away from any protected areas. In addition, the surrounding landscape has already been modified, and the potential new threats are much lower than in other locations.

1.11 Findings and recommendations

Method of Programme implementation

The basic positive environmental impact of the implementation of the Programme is to be the reduction of the negative impacts connected with the current operation of the energy sector, especially by lowering the social costs of energy generation and reducing the emission of greenhouse gases (chapter 5). However, to achieve these objectives, we must start the planned activities immediately and implement these projects in accordance with the adopted schedule. Otherwise, the costs of Programme implementation will not bring the expected effects.

Selection of an optimum location for the future nuclear power plants is the key aspect of the Programme – many environmental impacts of the planned project will depend on the specific location. Technologies adopted for this project should use the latest and best available technological options at the implementation stage. When selecting the location, we should consider and analyse the available technologies and economic feasibility of the combined heat and power generation in a nuclear facility.

Implementation of the Polish Nuclear Programme should not be an isolated effort. It should rather function as an important element within the larger framework of Poland's strategy for the modernisation of the country's energy sector. At the same time, under the Polish Energy Policy until 2030, the country must modernise its conventional power plants, improve its energy efficiency (also through the improvement of the existing transmission infrastructure), and develop new RES systems in accordance with their actual power generating potential, etc. However, As the analysis of energy security alternatives indicates, there are two sides to every story. Objectives set for the Polish energy sector cannot be fully achieved without the implementation of the Polish Nuclear Programme, but also implementation of the Polish Nuclear Programme alone will not bring the expected results.

Actions reducing the scale of potential social conflicts

Social approval and acceptance is required for the development of new electricity generation methods in Poland in general, and for the development of nuclear power in particular. The nuclear power sector should develop in such a way as to prevent the escalation of potential social conflicts and to ensure full transparency of all actions and an effective dialogue with all stakeholders. It is important to use the best available technologies and practices that ensure safety in a nuclear power plant, but at the same time the adopted goals should be achieved – the supply of cheaper and 'cleaner' electricity, protection of the natural environment, and improvement of the living conditions for Polish citizens. Ultimately, nuclear power plants must become an element that will diversify energy sources, satisfy the demand for electricity, and guarantee the country's energy security. At the same time, each and every citizen shall have the inalienable right to information on the operation of nuclear power plants and their impact on the environment (save for any information that could compromise nuclear safety). To achieve this objective, an information and education programme should be implemented. However, this programme cannot be used as a propaganda tool for nuclear power; instead, it should provide the source of reliable information to the society and highlight the benefits of nuclear power and its proper place among different energy production methods.

In order to implement these objectives (specified in more detail in previous Chapters of this Report), the authors suggest the following action plan (again, described in more detail in the main Report):

- A genuine debate with the society on the development of nuclear power in Poland using mass communication channels – the press, radio, TV, Internet, and other media.
- Face-to-face meetings with inhabitants of the regions where nuclear power projects are planned, with the involvement of nuclear power and environmental protection experts, and – at a later stage – authorised representatives of potential investors.
- Collecting feedback on the expectations and concerns of Polish citizens regarding the planned development of nuclear power and considering this feedback when designing potential nuclear power plants.
- Using the experience of other countries in the construction and operation of nuclear power stations to ensure the highest safety and the lowest negative environmental impact. It includes both the implementation of state-of-the-art technologies and development of the necessary implementing legal provisions and methods of management of nuclear facilities.
- Education of the society, including at all levels of school education, as regards the modern methods of electricity production – including a broad presentation of nuclear power as one of the methods of effective diversification of energy sources in Poland.
- Support for the local initiatives such as the project planned in the Municipality of Gniewino - organisation of a training centre for teachers of natural sciences, not only from the Pomorskie province but for the entire country.. We recommend that the intensive training programme should be supported, and its results and lessons learned communicated to other regions of Poland.
- Support for the projects that focus on the creation of civic society in Poland – a society of people who protect their living environment, use the best available environmental protection solutions, and save energy and natural resources to preserve them for future generations.
- An honest debate with opponents of nuclear power in order to eradicate false, unconfirmed, and harmful data and information that can mislead the society – on both sides.

As regards the follow-up measures, regular and reliable public opinion polls should be organised by professional research companies using the appropriate methodologies and tools of statistical analysis.

Actions at the Environmental Impact Assessment stage

At the Environmental Impact Assessment stage, the proposed course of action will include:

- a comprehensive analysis of the necessary infrastructure that will be required in the location of the planned nuclear power plant, and obtaining a single environmental decision (decision on environmental constraints) for the entire project.
- a application for the decision on environmental constraints for three alternative locations. This will make it possible to conduct a detailed analysis of alternatives for at least three alternative locations of nuclear power plants. The final location will be selected upon completion of the report and the social consultation procedure. This approach will guarantee that environmental protection will be given the same priority as social and economic aspects of the project.

Protection of surface and ground waters

Negative impacts of the nuclear power plant on surface waters may be kept at a minimum or eliminated altogether by using the proper technologies and selecting the optimum technological parameters that are described in detail in this Report. The planned nuclear power plant will increase the demand for cooling water. Therefore, selection of the optimum technology and cooling system is of key importance in the decision-making process as regards the location of the project.

To keep the negative impacts on surface waters at a minimum, special attention should be paid to the following aspects:

- rational management of water and effluents, as well as the cooling water system (including application of best available solutions in the design of cooling water systems and other components - to minimise the non-recoverable losses of water and emissions of harmful substances to the environment).
- installation of systems for the collection, treatment/pre-treatment, and discharge of effluents and sewage;
- adoption of strict limits for the concentration of substances used in processes in the nuclear power plant;
- monitoring of effluents for the concentration of certain substances;
- monitoring of the condition of water bodies to which treated effluents and sewage are discharged;
- regular maintenance of all plant and machinery and transmission networks.

According to the analysis of the existing geological and hydrogeological conditions in areas considered as the potential locations of nuclear power plants, the degree of sensitivity of the ground and rocks to the potential infiltration and penetration of pollutants to ground waters is very diversified, depending on the location. Therefore, this important factor must be taken into account when selecting the most optimum location. During normal operation of the nuclear power plant, the negative impacts on the condition and quality of groundwater resources will not increase.. However, the scenario may be quite different in the event of a breakdown or an uncontrolled leakage.

In the implementation phase, the negative impacts on the condition of groundwater may be reduced i.e. based on:

- proper location and organisation of construction site facilities,
- good technical condition of construction equipment,
- reduction of the area of land occupied by the construction site to a minimum,
- introduction of any possible safeguards to prevent the release of petroleum products to the ground and water environment, for instance by designating special parking areas (with protected surface) for construction machinery and equipment.

In the operation phase, the level and quality of groundwater must be monitored.

Special attention should be paid to effective protection of groundwater intake points, usable groundwater bodies (especially major ground water reservoirs) and their protected areas, as well as local water bodies of lower importance, in particular when they are not naturally isolated from the surface and if they are used as a source of water supply.

Protection against radiation

It must be ensured that the Parliament passes the relevant laws that will guarantee radiological protection and safety of people. The relevant information should be disseminated by the press and other media.

The necessary weather data and other information required to assess the environmental impacts of the nuclear power plant should be collected for at least two leading locations, and preferably for 3 or 4 typical locations, with due consideration given to the existing local conditions, even if it involves additional costs. Then, the necessary safety data sheets should be collected from the suppliers of nuclear reactors and used as a basis for an independent assessment of their environmental impacts during normal operation and in emergency conditions.

The investor and nuclear regulatory authorities should conduct a preliminary verification of nuclear safety of the proposed projects and nuclear regulatory authorities should approve the areas designated as restricted-use areas and areas of potential mitigation measures for each type of proposed nuclear power plants. The society should be then informed of the limits of these areas. It must also be ensured that the investor considers the level of safety for a given reactor type when analysing bids in the procedure of public procurement for the supply of reactors for Polish nuclear power plants.

Before the commencement of any construction works, the complete measurements of the existing level of radiation in the ecosphere in the area of the planned project should be taken. Results of these measurements will serve as a point of reference to determine the environmental impact of the nuclear power plant and to define the target radiation level to be achieved after nuclear decommissioning. It is of key importance, because radiation levels generated by a nuclear power plant in normal operating conditions are very low, and it is difficult to distinguish it from natural background radiation. These analyses should include natural and artificial radioactivity of the environment (i.e. both natural and man-made radioactive isotopes) as well as radioactive pollution affecting the inhabitants of the area in the vicinity of the nuclear power plant. A well-prepared programme of comprehensive radiometric measurements adjusted to the specific locations should cover the area of 15-25 km around the nuclear power station. More details on the required measurements are presented in the main body of the Report. Before the commencement of any construction works, assessment of the health condition of the local population should be conducted, to serve as a point of reference when determining the radiological impact of the nuclear power plant in the future. It is the only way to define a baseline for any future analyses. Additional measurements and analyses should also be performed to compare this data with other regions of Poland and other countries.

Monitoring solutions and proposals to prevent, reduce, or compensate the negative environmental impacts on the objectives of Natura 2000 network and the protected Natura 2000 sites and their integrity

To reduce the negative environmental impacts of a nuclear power plant at the construction and operation phase, the following actions should be taken:

- construction plans and specifications should be consulted with experts in the field of botany and zoology, so that any threats to terrestrial or aquatic animals and plants are identified and minimised as they occur;

- construction works should be performed at an appropriate time that does not interfere with the nesting period of birds;
- buildings and construction machinery should be provided with sufficient lighting in the construction and operation phase to prevent the increased death rate of birds caused by collisions;

If any serious and irreversible impact on any Natura 2000 site has occurred, the appropriate compensation measures must be introduced.

Organisational activities

It is recommended that a single-person unit be established at the Nuclear Energy Department of the Ministry of Economy, responsible for the monitoring of environmental impacts and implementation of the necessary mitigation and compensation measures. This unit would function within the framework of the Ministry of Economy but report the results of its works to the Minister of the Environment. Based on this approach, environmental aspects will be given the same priority as any social and economic aspects.